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SUPPRESSION OF WATER USE BY PHYSICAL METHODS*

There are two purposes for suppression of water use by consumers: conservation, or reduction of use over a prolonged period (seasonal or annual); and peak demand suppression (either maximum day or peak hour demand). Conservation and peak demand suppression have considerable effects on the size or capacity of facilities required to provide a reliable supply to the consumer.

Conservation and peak demand suppression can be achieved in several ways: by voluntary or mandatory programmes or by economic (tariff) methods. In a sense all suppression methods function by economic constraints; as a consumer uses less water he also saves money. Of course, economic incentives can be made more persuasive, in the form of penalties for not using mandated methods or large surcharges for excess water use. Discussed here are physical techniques for reducing water consumption that can be voluntary or mandatory, with or without strong economic incentives.

Conservation

Effective physical methods for reducing long-term *per capita* consumption are directed mainly at internal plumbing of domestic, commercial, and industrial customers where reductions in consumption would be realized on a year-round basis. The fittings that have been investigated most thoroughly include toilets, washing machines, and showers. Howe and Vaughan (1) reported that an over-all saving of 32 per cent of residential use, equivalent to approximately 70 litres per day, could be achieved by requiring replacement of inefficient toilets, washing machines, and showerheads. To realize such a saving would require mandatory regulations because there is little economic benefit to the consumer in buying replacement devices.

The California Department of Water Resources (DWR) (2) concluded that the following savings could be realized in domestic use if improved fittings were utilized: toilets, 10-18 per cent; showers, 9-12 per cent; clothes washers, 0-5 per cent; mean – 6-12 per cent. Potential *per capita* savings would be 19-38 litres per day for the three fittings.

A study made by the Los Angeles Department of Water and Power (3) indicated a savings of 9 per cent by the use of restrictive showerheads, toilet tank dams, and flow restrictors. The 9 per cent figure is a preliminary estimate and includes certain voluntary conservation factors, but it correlates with the California DWR data.

Perhaps the most comprehensive and thorough study on water use to date is a project completed in 1966 by Johns Hopkins University for the Federal Housing Administration.(4) The project, which collected extensive data from 39 areas in the United States, established models and analysed the data by regression equations. Many of the conclusions that can be drawn from the study relate to economics but several significant factors pertain to physical facilities, perhaps the most interesting being that metering has little effect on houshold consumption. However, the study established that a septic tank system suppressed household consumption by 15 per cent per annum as compared with homes connected to public sewers.

A summary of water-saving devices and the estimated water use reduction achieved by them, taken from a 1974 Environmental Protection Agency (EPA) report (5) and from other references, is shown in table 1.

Peak demand suppression

Conservation benefits mainly the source of supply. The other components of the water supply system are designed to provide for maximum day, peak hour, and fire demands. The distribution of investment shown in table 2 indicates potential cost savings that could be obtained by water use suppression methods. Conservation could reduce future capital investments by 5 to 40 per cent of total utility capital investment. Demand suppression, by comparison, could affect treatment, local pumping stations, transmission mains, service reservoirs, and distribution facilities, which comprise an estimated 50 to 75 per cent of total investment.

It is estimated that 54 per cent of California residential consumption is used for interior (household) purposes(2). The Johns Hopkins study (4) estimated national household use percentages as 54 per cent for metered services and 34 per cent for unmetered services. The study also determined the peak factors for metered services as 2.15 for peak day to average day and 5.4 for peak hour to average hour. Since so major a portion of water utility investment is made for components designed to meet peak factors (50 to 75 per cent), it can be argued that emphasis in water use suppression should be directed toward peak suppression rather than conservation.

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Table 1. Summary of household water-saving device

Device	Water use reduction		
	Litres/day	Gallons/day	Percentage
Toilet improvements	28-66	7.5-17.5	12-27
Faucet aerators	0-2	0-0.5	0-1
Flow limit valves, all fittings	0-2	0-0.5	0-1
Shower flow limiting	0-28	0-7.5	0-12
Pressure-reducing valves	0-61	0-16	0-20
Metering	0	0	0
Septic tanks	133	35	15
Improved clothes washers	0-30	0-8	0-5
Improved dishwashers	0-23	0-6	0-4
Hot water pipe insulation	0-23	0-6	1-4
Total	265	70	52

Table 2. Proportion of capital investment in water utility components

Component	Estimated percentage of total investment		
	Local surface supply	Distant surface supply	Ground-water system
Basic source	30	40	5
Treatment, local pumping stations, transmission mains, service reservoirs	30	30	40
Distribution system services	25	20	35
Fire protection	15	10	20

Under maximum day conditions more than 75 per cent of water may be for exterior use. Many factors contribute to the rate at which consumers use water under maximum day conditions, but one point is dominant: it is the affluent who place the greatest demand on water systems during hot weather. The Johns Hopkins study established that, in the western United States under maximum day conditions, two factors can be directly correlated to demand: potential evapotranspiration and property value.

One method of suppressing peak demands is to charge more to consumers using excess water under peak demand conditions. However, such methods must also be equitable. Discussed below are physical suppression facilities that also produce equity.

Physical suppression methods

Meters. Under maximum day conditions, meters can suppress demand by 25 to 58 per cent (2, 4).

Pressure regulation. Pressure reduction is required by the California Uniform Plumbing Code (6) for pressures in excess of 5.62 kg/cm^2 (80 pounds per square inch). Water system pressures in California are generally within the range of 2.80-9.84 kg/cm^2 (40-140 psi). Most services operate at pressures below 5.60 kg/cm^2 (80 psi), but in most cases 2.80 kg/cm^2 (40 psi) would provide an adequate supply. Pressure regulation reduces leakage and maintenance of faucets and toilet valves, providing a year-round water-saving feature that is equitable and reliable.

A study by the Washington Suburban Sanitary Commission (7) reported over-all conservation of 16 to 24 per cent by reducing pressures by 4.92-8.44 kg/cm^2 (70-120 psi) to an average of 3.52 kg/cm^2 (50 psi). Maximum day suppression was not investigated, but the capacity to peak would have been reduced theoretically by a mean of 27 per cent. In practice, maximum day demands would not be reduced by the theoretical figure, but by a lower amount because of an offsetting increased length of sprinkling by many consumers. There are no available statistical data for maximum day demand suppression resulting from pressure regulation. Suppression figures would vary depending on maximum day operating pressures within a service area and other factors, but it is possible that reductions in the range of 1 to 10 per cent could result. A pilot programme for investigation of the effects of pressure regulation is definitely needed.

Flow restrictors. A distribution system's required peaking capacity could be reduced by the insertion of flow restrictors on services at the meter. Such restrictors could be sized to adjust for service length, system pressure and site elevation so that all consumers in a defined service classification would have the same flow capacity at the meter. Flow restrictors are simple orifices, easy to install, and accurate. More sophisticated variable size orifice controllers are available but offer little advantage over fixed orifices in limiting flows. The optimum method of service classification would be a combination of pressure regulation and orifice flow regulators. It might also be necessary to provide a pressure (above a selected basic pressure) to consumers who have irrigation systems or other fixtures requiring higher operating pressures.

Service diameters. Limiting the diameter of services has been practised as a peak suppression method by most water utilities. The relative capacity of different services is listed in table 3.

A half-inch galvanized steel service 30 m (100 ft) long, with a distribution system pressure of 3.52 kg/cm^2 (50 psi), will provide a flow of approximately 0.25-0.5 litres per second (4-8 gpm), depending on the condition of the piping.

Service size limitation is an effective method of suppressing demand and is used as such by most

Table 3. Service capacities

Service size (inches)	*Material*	*Flow (litres/second)*
½	Galvanized schedule 40	0.5-1.0
¾	Galvanized schedule 40	1.0-2.0
1	Galvanized schedule 40	2.0-4.0
½	Copper	1.0
¾	Copper	2.0
1	Copper	4.0

Table 4. Summary of physical peak demand suppression methods

Description	*Estimated maximum day demand reduction*		*Cost per service (US dollars)*	*Comments*
	Range (Percentage)	*Mean (Percentage)*		
Service meters	25-58	40	80-400*	
Pressure regulation	0-27	5	45	Should be investigated
Flow restrictors	0-20	5	10	Should be investigated
Service diameter limitations	-	-	-	Generally now efforced
Hose meters (voluntary)	2-4	3	10	Study required
Hose meters (mandatory)	5-15	10	10	Difficult to administer
Spinkler timers	-	-	200	Expensive
Moisture sensors	0-20	10	400	Not yet proven for residential use
Landscape design	0-50	-	-	Essentially a voluntary method

* The higher amount refers to existing services.

utilities; however, provision should also be made for applications requiring greater flows.

Hose meters and timers. That lawns and gardens are overwatered is well recognized. It is estimated that the level of overwatering in California is as high as 20 per cent (2). Other estimates have placed the overwatering figure at 78 per cent for parks and recreational facilities (8). In most residential cases, sprinkling is accomplished without any timing or metering, although timers are used on many fixed sprinkler systems. Overwatering is essentially a peak demand problem that, if reduced, would significantly suppress maximum day demands.

Untimed sprinklers represent most of the demands in California urban areas under maximum day conditions. In a large percentage of cases, sprinklers remain in operation longer than intended because of oversight, resulting in higher than necessary peak hour and peak day factors. If timers or hose meters were encouraged or

mandated, substantial reductions in peak demands could result. There is no known published data on the effect of a voluntary or mandatory consumer timer or hose meter programme. Hose meters are inexpensive ($US7 to $US15 per unit), but timers for sprinkler systems can cost hundreds of dollars for a complete fixed sprinkler system on a typical lot. However, it would be possible, without significant investment in equipment, to investigate the effect of both meters and timers on conservation and peak demand suppression. One voluntary hose meter utilization programme has been judged to be 2-4 per cent effective (9). A mandatory programme could possibly suppress peak day demands by 5-15 per cent, but might be difficult to administer. Mandatory restrictions on timed sprinkler use would reduce peak hour demands, but would have no effect on maximum day demand.

Moisture sensors. Moisture sensors are used for parks and recreational areas but are not economical for residential sprinkling applications. If they were used in conjunction with timers, it is estimated that maximum day demands would be reduced by 10 per cent (2). It is possible that sensors could become economical for residential use, but it is doubtful that their application would become common enough to effect a reduction in maximum day demands.

Landscape design. Landscaping methods could be considered as a physical means of water conservation and peak demand suppression, although it is difficult to dictate taste. Thus landscape design would have to be considered a voluntary method. Soil preparation, ground cover materials, paving area ratios, and selection of drought-resistant species could contribute to saving water. Landscape design and the use of unplanted or paved areas require aesthetic and economic judgments, but a change in current practices could reduce demands over a broad range.

Residential maximum day suppression. A summary of physical maximum day suppression methods is given in table 4. The total potential amount of suppression for the methods listed cannot be computed by adding amounts saved by each method because some methods are not cumulative. Furthermore some of the methods listed may not be feasible for a particular system.

Summary

Water use suppression methods can be classified as conservation methods, aimed at decreasing the supply of water required, and peak demand suppression methods, by which system capacity to meet peak demands can be reduced. Studies of physical conservation methods have shown that long-term residential water use can be reduced by 6-12 per cent. Peak demand suppression methods have not been studied as thoroughly as conservation practices, although the potential for savings in capital investment seems to be even greater. Possible physical methods to achieve peak demand suppression include service meters, pressure regulation, flow restrictors, service diameter limitations, hose meters, sprinkler timers, moisture sensors, and landscape design.

References

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SANITARY SEWERS FOR DEVELOPING COUNTRIES – NECESSITY OR LUXURY?*

Transporting fecal matter by water gained widespread popularity during the industrial revolution; the basic concept has remained unaltered to this day. Coming in the Victorian era when "cleanliness was next to godliness," the concept of flushing away one's waste was attractive indeed. Sewers were advocated as the solution to the urban waste problem. The waste had to go somewhere; most often it was discharged into and effectively treated by a river. Inevitably, with urban growth and increased volume and complexity of waste water, the self-purification capacity of rivers was surpassed. Treatment of waste water before discharge became an expensive necessity.

Meanwhile in China, the technological era had not arrived; human waste was looked upon as a natural source of nutrients for plants. Instead of being regarded as an undesirable source of river pollutants, the growing cities were viewed as a valuable source of fertilizer, a place where a farmer could purchase excreta from a housewife at relatively little cost.

The two approaches to essentially the same problem exemplify the philosophical disparities between the two societies. To Western thought human excreta are useless, undesirable waste products to be gotten rid of as quickly and inoffensively as possible. To the Chinese, nightsoil is a desirable resource. With economic and population growth, the exhaustability of water resources is putting an end to indiscriminate discharge of wastes to the environment, yet alternative approaches that are socially acceptable in Western eyes are expensive. In contrast, the Chinese continue to use excreta for agriculture. By so doing they provide a positive monetary incentive for pollution control.

Organizations providing aid to developing nations have used both approaches to waste disposal. Sanitary sewers and waste water treatment plants have been built in many cities; more are in progress. In addition, recovery of waste for agricultural use, using biogas plants to convert animal and human waste into useful material, has become increasingly widespread. For widely different reasons, neither has proven the universal solution.

Sewers not appropriate for developing nations

When the Western engineer designs urban waste disposal for a less developed nation, he almost invariably bases his design on waterborne sewage transport. This involves dilution of the waste in its most concentrated form with potable water solely for transportation. The resulting sewage, mostly water, is flushed through a system of subterranean pipes and pumping stations to one discharge point. Because direct discharge of large volumes of waste is detrimental to the receiving water, the objective then becomes one of repurifying the water and reconcentrating and treating the waste. In short, diluting waste for transportation and then concentrating it at a treatment plant does not make sense economically or in terms of resource conservation.

Sewers and treatment plants are expensive. On a per household basis, they are far more expensive than colour television sets. Still, urban planners insist that sewers are both desirable and necessary; why?

First, there appear to be no alternatives: no technologies to fill the gap between the unsatisfactory pit privy and sewerage. Such is not the case. Systems in use in developing countries are appropriate and could be upgraded and properly designed to provide adequate service at low cost. In Botswana, Africa, for example, research showed that improved pit privies, Reed Odorless Earth Closets and double-vault composting latrines efficiently overcome health and nuisance hazards. A World Bank cost comparison showed all such systems to be significantly less expensive on a per household basis than sewerage.

Second, concepts, practices and attitudes imported mainly from the West have artifically increased the desires of policy makers for technologies their people simply cannot afford. Public officials, eager to impress their constituencies and the rest of the world with development or progress, often want nothing less than the latest and most sophisticated technology the industrialized world has to offer.

Third, the dependent developing country often requests from bilateral aid or international organizations feasibility studies and master plans for waste disposal systems. Western engineering consultants are contracted. Consulting firms are constrained by lack of experience, so they limit their choice to piped sewerage. In several cases there has been outright refusal to consider alternative methods.

This attitude is understandable. Consulting engineering firms are professionally responsible for the

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* By Michael G. McGarry, Associate Director, Health Sciences Division, International Development Research Centre, Ottawa, Canada. Reprinted with permission from American Society of Civil Engineers (ASCE), *Civil Engineering*, vol 4, No. 8 (August 1978), pp. 70-75.

designs they propose; their reputations depend on the success of implemented schemes. As such, they can hardly be expected to endorse technologies with which they have no experience. There is a case here for the development in developing nations of engineering firms familiar with local conditions and not bound to the design criteria and technologies of industrialized states.

Sewerage not cost-effective

Despite the inaccuracy of assessing intangible benefits, a benefit-cost analysis of sewerage in developing countries did illustrate the economic characteristics of urban sewerage. The study showed generally that:

(a) Construction periods are necessarily long because of budget constraints;

(b) Benefits accrue from sewerage in the distant future, because sewer mains and laterals must be complete before many house connexions can be made;

(c) Large investments are required during the first stages of sewer construction. These are not matched by early revenue returns or by health benefits;

(d) For a municipality to invest in sewerage, a very high value must be placed on intangible environmental and amenity benefits, because health benefits are minor compared to the capital outlay required for construction and maintenance of the system.

Under the guise that any planning exercise is worth while, that baseline data will be useful when sewers can be afforded and that the plan is "given" to the recipient country without cost, development of master sewerage plans continues. There are, however, many hidden costs to this exercise in negative aid.

First, funds spent for master plans (typically $US0.5 to 1 million) could be better used elsewhere.

Second, a large number of qualified personnel from the developing country spend valuable time they can ill afford to waste on this useless planning exercise.

Third, after being shelved for several years, the plans fall out of date and are seldom used.

The most adverse side effect is the perpetration of the misconception that there are no other financially feasible methods of waste collection and disposal. This results in the indefinite postponement of rational attempts to solve urban sanitation problems.

Developing countries are having considerable difficulty providing urban waste water management services, because the technology they are trying to apply is inappropriate. Sewerage transfered from industrialized States is capital-intensive during construction and labour-conserving during operation: quite the opposite of required economic characteristics.

Bioconversion no panacea as disposal alternative

The biogas (or bioconversion) plant has recently gained wide publicity as a resource recycling technology appropriate for developing countries. It operates on the principle used in conventional anaerobic sewage sludge digestion. The digestion tank, made of concrete or flexible butyl rubber, is daily fed water and organic farm and household waste, sometimes including human excreta. The mixture ferments without air to produce "biogas" (carbon dioxide and methane) which is used primarily for domestic cooking and lighting.

The biogas bubbles up out of the tank's digesting material to be caught in a gas holder resting on the tank's liquid surface. The gas holder rises and falls with production and use of the gas, which is drawn off through a flexible tube to the nearby household. The digested waste material comes from the tank as an odourless and innocuous slurry, which can be used as fertilizer either directly or after drying or composting with other farm wastes. Biogas plant technology is indigenous to Asia. A great deal has been published about the original work carried out in India, where 36,000 biogas plants have been built; parallel developments have taken place in the Republic of Korea and China, where 27,000 and at least 80,000 plants, respectively, have been installed.

Technically at least, the concept has considerable appeal and has gained wide popularity in the West with the rise of the appropriate technology movement. Many demonstration units have been built in the West, but few have enough waste to operate continuously. More serious fundamental research is being carried out in universities of the United Kingdom, the United States and Israel, but the technologies being considered are too high to be applicable to the rural peasant.

International agencies and appropriate technology groups have found biogas highly attractive, particularly the United Nations Economic and Social Commission for Asia and the Pacific, which held meetings in India and the Philippines on the subject. These were attended by biogas technology advocates and focused, once again, on the hardware and how it should be promoted across Asia without concern for its many failures in the past.

Success of the biogas plant in Asia has varied, having been affected by numerous interrelated factors. The dominant motivation for adopting biogas plants varies between and even within countries. Using the gas for cooking does, however, appear to be the primary benefit, with the agricultural value of the slurry often being given only marginal emphasis. The more hidden benefits related to public health and reduced deforestation are recognized only by the Governments that provide grants or soft loans (but decreasingly so) to individuals interested in installing biogas units. The Republic of Korea is now withdrawing credit from

farmers wishing to install biogas units. Credit has been essential to the expansion of biogas programmes in India and the Republic of Korea.

The major constraints to biogas utilization in rural areas pertain to non-technical factors. In particular, extension services, needed for maintanance and repair, are often lacking; likewise, banking and loan facilities are commonly cumbersome. In most situations where plants are individually owned, only wealthy farmers can afford them, because the landless labourer or tenant has neither the construction capital nor enough animals to feed the system. Problems also occur where water and land are not readily available; in particular, the land for slurry drying or composting is costly in urban or periurban situations.

Evaluating the biogas plant is difficult. A dearth of basic information exists with respect to the capital costs of the biogas unit, costs of land, the dung produced by animals, seasonal fluctuations on demands, availability and value of resources, and products, product yields, etc. Before biogas plants are propagated across the developing world, we must support the determination of site-specific, socio-economic evaluations, the innovation of less expensive designs and the identification of those social and economic conditions under which biogas plants have the greatest chance of success.

CITIZEN PARTICIPATION FOR SUCCESSFUL VILLAGE WATER SUPPLY*

In the eyes of "developed society", clean water is a prerequisite for comfortable, healthy living. This is feasible because acquiring water takes up only a very small percentage of the American or European income, and because the thought of a cholera or typhoid epidemic running through New York or London via the water supply is truly horrific. Consequently, there is a serious danger that international water engineers will transfer these concepts and practices to developing regions where such diseases as cholera and typhoid are commonplace, indeed endemic; where disease is transmitted in many ways other than by water; and where the people simply cannot afford to pay for water supplies. These regions tend to accept external help and with it externally determined development priorities, which may have little or nothing to do with their real needs.

However, there are areas in dire need of improved water supplies, where during the dry season women must spend a good portion of the day walking as much as 10 km to scrape water from a muddy hole. These water-scarce areas justifiably demand first attention, but this justification is based on labour and time savings, not on health.

Design systems villagers can maintain

During the 1977 United Nations Water Conference in Argentina, the Mexican delegation suggested that the following be included in the Mar del Plata Action Plan:

"It is recommended that the effective participation of the public is the key for success of programmes of water management and that the lack of local participation has frequently resulted in ineffective programmes."

The phrase "lack of local participation has frequently resulted in ineffective programmes" is confirmed by the report on community water supplies, in which it was stated that rural water supply systems had sometimes been constructed at great expense, only to remain idle owing to lack of maintenance.

Without maintenance, no water system will long continue to serve. Ancient Roman aqueducts could carry water to vital urban centres only because their channels were designed and built to standards that Roman aqueduct maintenance crews could deal with. Indigenous Latin American water systems in some urban areas have functioned well because their technology has been within the scope of the maintenance capabilities of users. Split bamboo and carefully levelled rock channels, all user-maintainable and renewable, have traditionally been part of these systems. Users can maintain such systems because they have essentially been user-planned and built. The parameters of system maintenance are determined by the design of the system.

The kind of maintenance needed is often a direct result of effective participation in planning. Included in this seemingly simple statement are many more factors than have usually been recognized in the past. National and international organizations have become increasingly aware of the potential of village people for planning, learning, managing and changing their water-use patterns, when they become truly involved in understanding this process as part of improving their standards of living.

A Mexican village water supply project completed 20 years ago illustrates this point. The village of Santa Maria, with aid agency assistance, constructed a water supply, whose success can be attributed to public participation from the very beginning. The impetus for the project came from a village survey conducted by young rural women being trained as grass-roots "home demonstration" agents. As a result of interviews with village leaders and with families in their homes, those young women helped the people define their resources and needs. Safe drinking water emerged as their paramount development priority.

Two private voluntary agencies, CARE and the American Friends Service Committee (AFSC), looking for ways to combine their limited resources for maximum effectiveness in meeting community needs, had arrived at the same conclusion: potable water was the greatest need of rural villages. With CARE in Mexico taking the initiative, the contributions of international, national and local agencies were co-ordinated to respond to the locally defined needs. An engineer from the Government of Mexico confirmed the feasibility of well-drilling as a source of good water in the area, and agreed to supervise the technical aspects of the project. The World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) recommended a type of well-drilling equipment (Bucyrus-Erie-W 20), which they were using, and offered to train operators. AFSC agreed to assign four volunteers for training for the project, and CARE provided the equipment recommended by WHO.

The people in the village formed a water committee which raised money and set up a special bank ac-

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count, which proved sufficient to cover local costs for water pipes and gasoline for the drilling rig. The amount of money was not the most important thing; the process was. The community also organized a hospitality committee so that nearly every family in the village shared in housing or feeding the four volunteers. The initial result of all this was modest, a simple handpump on the village square, but it produced clean water, which people preferred to the polluted drainage water they had formerly had to use. Ten years later, the water from the same well was being pumped up electrically to a water tank and distributed throughout the village. The village still has a water committee; its members include children of original committee members. They collect a monthly fee to pay a caretaker to maintain the well.

Successful projects are models for others

Today, drilling for potable water may seem commonplace; but 20 years ago in Mexico, this project created enough interest to make front page headlines in the Mexican newspapers and appeared in the *New York Times* and other publications. One immediate result was a request from the governor of another State in Mexico for a similar project. When he understood that the key to the success of the project was neither the CARE rig nor the AFSC volunteers, but rather the participation of local communities and village workers, he successfully replicated the project using locally available equipment and local young men in place of the AFSC volunteers. The communities selected for this work were chosen on the same basis as the original villages, after a community survey by extension workers. The new villages also offered home hospitality to the well-drillers. This hospitality, like the village survey, was an integral part of village awareness, orientation and education for effective involvement.

Another success story: in Malawi, a small country in south-eastern Africa, village participation was the key to success in bringing piped water to more than 150,000 villagers falling in the water-scarce category at a cost of less than $3 *per capita*. The Department of Community Development and Social Welfare began on a small-scale by demonstrating that one could transport water through pipes from a perennial stream by digging all the trenches, laying the pipes, and constructing the concrete aprons and soak-away pits around the village taps. This initial demonstration mushroomed. Soon the demand for piped water outstripped their capability to deliver it.

Initially the piped water projects were small in size and made use of demonstrations and examples so that the villagers knew exactly what they were getting into. Now, large public meetings are held to ensure that commitments are fully understood and acknowledged by all. More important, this approach involves the people not only as labourers but also as decision makers. They are, to a large extent, responsible for the success of the system and are willing to be responsible for its continued maintenance and repair.

Examples of failures are not difficult to find; they exist in most African countries, where lack of maintenance and repair capabilities in rural areas is compounded by inappropriate well-drilling equipment and several varieties of handpumps more suited to the back garden of the Western farmer than the centre of a drought-prone, populous village.

In one Asian country, approximately 50,000 wells were drilled in hard rock in water-scarce villages at a cost of $40 million. An estimated 80 per cent of these wells are no longer producing water. The problem was not only technical; the pumps were installed with insufficient involvement of each village, the site for locating each village pump being selected by the engineer, not the village leader. The villager views the pump as belonging to the government department that installed it and therefore accepts no responsibility for looking after it.

In Bangladesh, clean water supplies to villages are being provided through a major UNICEF programme providing thousands of handpumps to villages to combat endemic cholera. The mere supply of handpumps has done little to alter wateruse practices and hygiene in the home. Consequently, it was not a surprise when the Cholera Research Laboratory in Dacca found no significant reduction in cholera in families using the handpumps for drinking water.

Conclusion

When people accept a project or programme as the solution to a need they feel, participation is more effective, their village wisdom is a guide to the choice of appropriate technology, and their understanding of the institutional arrangements can facilitate effective follow-up.

Engineers can do the technical planning to solve the problem of water supply, but the human element at the grass-roots level must be included for effective utilization and management. When, as in Santa Maria, full participation (meaning village-wide and from the beginning stage of planning) is evident, the new technologies and/or new approaches of meeting needs are usually possible.

WASTE DISPOSAL ALTERNATIVES FOR DEVELOPING COUNTRIES*

An extensive literature review (18,000 titles) conducted by the International Development Research Centre reveals several technologies for waste disposal between the unacceptable pit latrine and the too-expensive sewer system with treatment plant. These alternative technologies include improved pit latrines, the Reed Odourless Earth Closet, wet and dry vaults, and composting privies.

Improved pit latrines can be acceptable

The pit latrine, although unhealthy and unpleasant, remains one of the few technologies affordable by developing nations. Improvements can make the pit latrine more acceptable. One simple improvement is the pour-flush latrine. A pan at the lower portion of the chute maintains a water seal, which blocks the passage of odours and flies. About a quart of water is used to flush the contents into the pit. Problems with this system include blockage of the chute and lack of manual flushing, which allows exposure of waste to air.

Another improvement is a chute and pan arrangement; the pan is swivelled and counterweighted. The weight of the waste in the pan causes it to tilt and empty into the pit. A valve automatically refills the pan with water from a storage tank, ensuring regular flushing.

The Reed Odourless Earth Closet is an attempt to overcome some of the drawbacks of the pit latrine without significantly increasing the cost. It consists of a large pit (1 x 2 x 3 m deep) covered by a concrete slab. The squatting area located to one side of the slab is connected to the pit by a sloping chute. A vent pipe built into the slab draws air down the chute and up the pipe. Construction must be airtight. The closet, reportedly odourless and free of flies, has a service life of up to 20 years.

Vaults reduce ground-water contamination

One problem with pit latrines is that seepage can escape and contaminate the ground water. One solution is to line the pit, converting it into a vault. If no water is added with the waste, the vault can be emptied by bucket (dry waste) or by vacuum truck (semi-dry waste). The alternative is the wet vault, which has two types: the septic tank (common in the United States, but often more expensive on a per household basis than even sewerage for urban areas of developing countries) and the aqua-privy.

The aqua-privy is a modified cylindrical septic tank, which is filled with water upon construction and replenished as necessary to maintain a water seal. A vertical drop pipe carries waste from a toilet bowl or a squatting plate to below the water surface. As with a septic system, solids sink to the bottom of the tank; overflow is discharged to a leaching field; and the tank sludge is removed periodically. If insufficient water is maintained in the tank, the water seal ceases to function, and flies and odours become serious problems.

A double-vault composting latrine consists of two compartments, each large enough to hold six months' waste. When one is full, the other is used, thereby providing a six-month composting period. Grass clippings, food scraps, leaves and animal wastes are added to the human excreta to maintain the carbon/nitrogen (E/N) ratio required for composting.

A double vault used in Viet Nam also has two watertight tanks, serving first for defecation and then for composting. Urine is channelled to a separate vessel, because the urine's nitrogen content can reduce the C/N ratio below the acceptable range. Before use, the bottom of each tank is lined with powdered earth. Feces are regularly covered with kitchen ashes to absorb moisture and to deodorize. When a tank is two thirds full, the surface is levelled, and the tank is filled with powdered earth and sealed to create an anaerobic environment.

An aerobic household composting system consists of a watertight tank (1 x 2 x 3 m long) with a sloping bottom. Waste introduced at the upper end mixes with kitchen and garden waste introduced lower down. Composted material moves towards the lower end and is periodically removed. The decomposition period is long, up to four years. Air ducts and a vent pipe promote aeration, evaporate humidity and, like the Reed Odourless Earth Closet, reduce odours. The sloping bottom permits continuous use of one tank by separating fresh from composted material.

Public health implications of alternative waste disposal methods

No single ranking of waste disposal technologies according to their effects on public health is possible. Good sanitation is certainly an important factor in promoting good public hygiene, but sophisticated waste disposal seems to be neither necessary nor sufficient

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for a high level of general health. Some African cities with waterborne sewage collection have high incidences of water-related disease. On the other hand, recent studies in Kyoto, Japan, showed no difference between the health of sections of the city served by sewers or septic tanks and that of those served by manual collection.

The crucial importance of social and educational factors in the improvement of public health leads to another conclusion regarding waste disposal technology. The most cost-effective method of improving sanitation may be a combination of low-cost technology (improved pit latrines, composting privies) and an educational programme on their effective use.

SELECTING SEWERAGE SYSTEMS TO FIT SITE CONDITIONS AND BUDGET*

About 28 per cent of the homes in the United States have no centralized sanitary facilities. According to the 1970 census, this means 19.5 million homes, with 58 million people, producing 3 billion gallons (11 billion litres) of raw sewage per day. Many of these homes are in low-density areas, on difficult terrain, and/or in poor communities that cannot afford gravity sewers. In areas with gravity sewers and treatment plants, a major cause of sewer moratoriums is the lack of adequate municipal collection facilities. Gravity sewers cost so much to install that some communities ban new development rather than extend the collection system.

In response to needs in rural areas and to the costs of conventional sewers, several alternative sewerage systems have developed. Some are newer than others, some more site-specific than others. But each is appropriate for consideration when new systems are designed for communities or individual homes.

The key to choosing from alternative systems is to select a cost-effective system most appropriate to site conditions. Then the system must be properly installed and maintained. Ensuring proper maintenance is a major push factor for establishing sanitary districts. The districts employ maintenance people to service equipment regularly and make repairs properly and quickly. The alternative sewerage systems highlighted here are pressure sewers, vacuum sewers and home aerobic units for preliminary treatment and mounds and evapotranspiration for effluent disposal.

Pressure sewer systems

Pressure sewers are a viable, economical alternative to gravity sewers in rural areas where homes are scattered over a wide area or in areas where gravity sewer construction is cost prohibitive because of high ground-water tables or difficult terrain. Pressure systems pump effluent from preliminary treatment units either to a main pressure line or to an existing gravity line. Small diameter pipes carry wastes under low pressure exerted by the effluent pump. Most systems are designed with 5-15 cm (2-6 in) diameter plastic or PVC piping laid parallel to the ground surface, just below the frost line.

There are two types of pressure sewers. Step systems treat the waste in a conventional septic tank and the effluent is then pumped to the main. The grinder pump system is a pump within a small storage tank. Waste solids are reduced in size through grinding, but not treated before being pumped to the main (see figures I and II).

The largest project using centrifugal grinder pumps exclusively is a combination pressure-gravity system in Lake Meade, Pennsylvania. A pressure sewer system was built because hilly terrain, high water tables, variable seasonal flows and waterfront properties made it the most cost-effective choice. The combination pressure-gravity system installed cost only two thirds that of a conventional system.

Pressure systems can be used throughout a community or for subdivisions, feeding into an existing gravity system. In rural areas, they are less expensive than gravity. The pipes are laid just below frost level, do not need to slope, and cost far less per metre to install. Pressure systems are less susceptible to ground-water infiltration. The plastic pipe is sealed, and very little initial seepage is allowed.

Pressure systems allow builders more freedom in site layout and can eliminate the need for sewer right of ways by following roads. In developments or subdivisions, wet service taps can be installed on undeveloped plots for easy hookup after site development.

The disadvantage of pressure sewers is that, although less expensive to install than gravity sewers, operational and maintenance (O and M) costs are higher. Not much O and M data are yet available, but on-lot costs are estimated at around $US 50/house/year. Maintenance of main lines is estimated to be about $US 160-480 per km per year. (Conventional sewer maintenance is about $US 2,400/km/yr.) For systems operational for 5-6 years, maintenance has not been a significant problem.

An additional disadvantage is the danger of extended power failures. The step system can hold 100-200 gallons, which is probably sufficient. Ninety per cent of the power outages in the United States are 9 hours or less. The grinder system has a much smaller tank. When grinder pumps replace septic tanks and drainage fields, the tank or field can be used to handle overflow (as shown in figure I).

For the home owner, pressure systems require more maintenance than a septic tank and drainage field. The installation cost to a home owner is about $1,500 to $2,500. Pressure systems are most cost-effective in small communities, or new subdivisions, where the cost of installing gravity systems is very high.

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* By David E. Johnson, Assistant Director, Technical Services Department, National Association of Home Builders, Washington, D.C. Reprinted with permission from the American Society of Civil Engineers, *Civil Engineering*, vol. 48, No. 9 (September 1978), pp. 90-93.

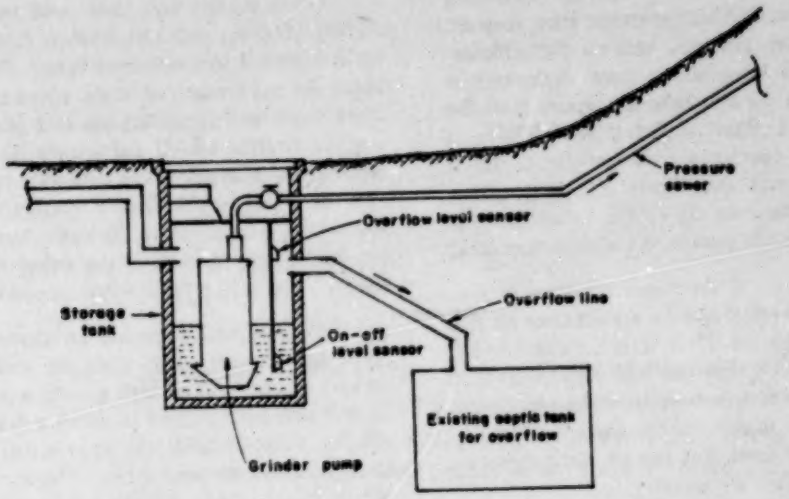

Figure I. Pressure system: typical grinder pump installation. Waste from house is reduced by grinder pump and pumped into main. To prevent overflow due to power outages or pump failures, existing septic tanks are connected to the system. For new houses, an overflow tank would be necessary.

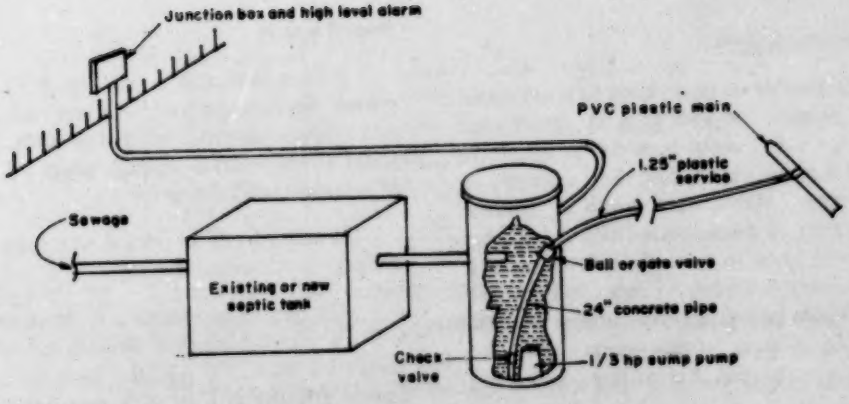

Figure II. Pressure system: typical septic tank effluent pumping. A variation of pressure sewer system. Waste is treated in septic tank and pumped to main by sump pump. System costs range from $ 1,500 to $ 2,500 per home, depending on site conditions.

Vacuum sewer systems

In this system, domestic waste is pulled through the collector lines to a central location by developing a vacuum on the line. The central station must keep the collector lines under constant vacuum for efficient operation. A special valve in the house connexion is designed to separate the atmospheric pressure from the vacuum in the main. When sufficient sewage collects behind the valve, it opens and waste and air are pulled into the vacuum main (see figure III). A sucessive series of plug reformations allows the vacuum in the collector lines to pull the sewage to the collection tank.

The applicability of the vacuum system is site-specific. Vacuum sewerage systems are efficient on flat lying or gently rolling areas. The system has a limited lift capacity (operating in about one-half atmosphere). It is also acceptable where homes are dispersed over a wide area or ground water is close to the surface. Pipes are laid just below front level, but require some grade to maintain the desired flow sequences.

Originating in Sweden, vacuum systems have been built in the United States for about fifteen years. There are operational vacuum sewers in Chicago, Virginia, Indiana and New Jersey.

Neither the equipment nor the hydraulics of vacuum sewers are as well developed as the pressure sewer. But equipment has rapidly improved and continues to do so. One drawback to the system is the energy required to maintain a constant vacuum. Another is the cost of the pumps: about $2,500 to $4,500 each. For home owners, the vacuum system is easy to maintain; the valve is the only moving part of the lot. For builders, the advantages are about the same as for the pressure system.

Individual home aerobic units

If it is not feasible to pipe wastes to a municipal system (either because the system is at capacity or because it does not exist), subdivision size or individual treatment units may be economical. For example, in Montgomery County, Maryland, a group of builders formed a corporation to finance, construct and operate a sewage treatment plant to serve their developments. The plant took about five years to review, design and construct. The facility permitted construction of 6,900 new homes and 240,000 m^2 of new commercial/industrial space in a county that has a 7-year-old sewer moratorium.

On some sites, aerobic units are an alternative to septic tanks. These units often consist of a presettling chamber, aeration compartment and secondary settling chamber (see figure IV). Raw sewage from the home flows into the unit, and is usually treated by a form of the activated sludge process. The effluent can be released to a drainage field or evapotranspiration bed. More sophisticated systems produce an effluent said by manufacturers to be sufficiently clean to disinfect and use for spray irrigation.

Home aerobic units cost more than septic tanks: $1,000-2,500 for unit and drainage field. Aerobic units are also subject to mechanical failure. The batch system holds one day's worth of waste, blows air into the tank, shuts down so that settling can take place, then pumps out the supernatant. If the pumps fail, they must be replaced immediately or the tank will overflow. Another type of home aerobic unit is attached to an existing septic tank and adds air to the waste. Mechanical failures are less serious because if the pump fails, the septic tank will continue to treat waste anaerobically.

Home aerobic units are an alternative to septic tanks and drainage fields when site conditions include rocky soil, clay soil or high ground water, or if homes do not have enough land to install a drainage field. An additional advantage of the units is that the effluent is sometimes cleaner than septic effluent. Disposal possibilities include spray irrigation, subsurface and surface discharge and evapotranspiration.

In Boyd County, Kentucky, the Appalachian Regional Commission built a system that included 36 individual home aerobic units and two multifamily units to serve 11 families. (The two larger units were possible because homes were grouped together.) The plants are managed by a newly-established sanitation district.

The disinfected effluent from the units is disposed of in several ways: some is spray irrigated; some discharged into streams, evapotranspiration beds, or subsurface dischage. These homes had previously piped raw sewage into nearby strems.

Mound system

The mound system (see figure V) is a viable and proven disposal method for septic tank effluent when subsurface drain fields are not possible. Effluent is disposed by percolation through select fill (usually sand) or by evapotranspiration.

There are three critical site conditions that do not permit subsurface drainage:

(1) *Slowly permeable soil.* Most municipal codes will not permit subsurface fields in soil with percolation rates over 24.4-27.6 min/cm. Mounds can successfully handle effluent in soils with percolation rates of 47.2 min/cm.

(2) *Ground-water table close to soil surface.* Most States require a minimum of 90-150 cm of soil from surface to ground water. Mounds, built primarily above ground, are acceptable with as little as 60 cm of soil between surface and ground water.

(3) *Crevice bedrock.* If there is less than 150 cm of soil covering crevice bedrock, subsurface drainage

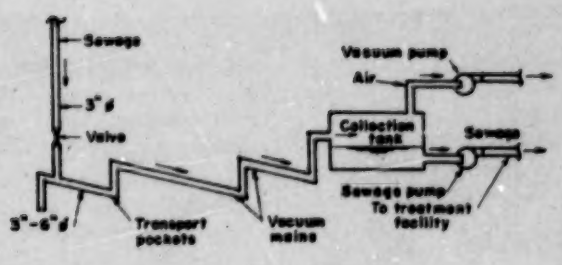

Figure III. Vacuum sewage system. When sufficient sewage collects behind the valve, it opens, waste is pulled to the transport pocket, and both ends plug with water. Water plug breaks, waste is pulled to next pocket, water plugs re-form.

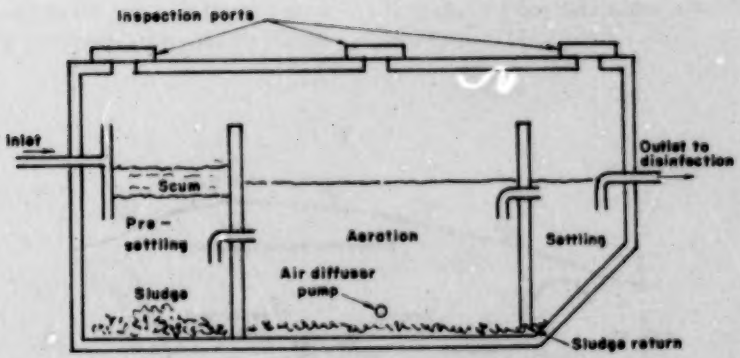

Figure IV. Typical individual home aerobic treatment unit. This is a composite drawing of home aerobic systems; several systems are marketed. Some systems produce cleaner effluent than others. Primary difference between home aerobic units and septic tanks: septic tanks treat sewage anaerobically and effluent is less clean. The biochemical oxygen demand (BOD) in septic tank effluent is 100-150 ppm, compared to 20-80 ppm for home aerobic plant effluent. The suspended solid matter (SS) is 40-50 ppm in septic tank effluent; 20-80 ppm in home aerobic unit effluent.

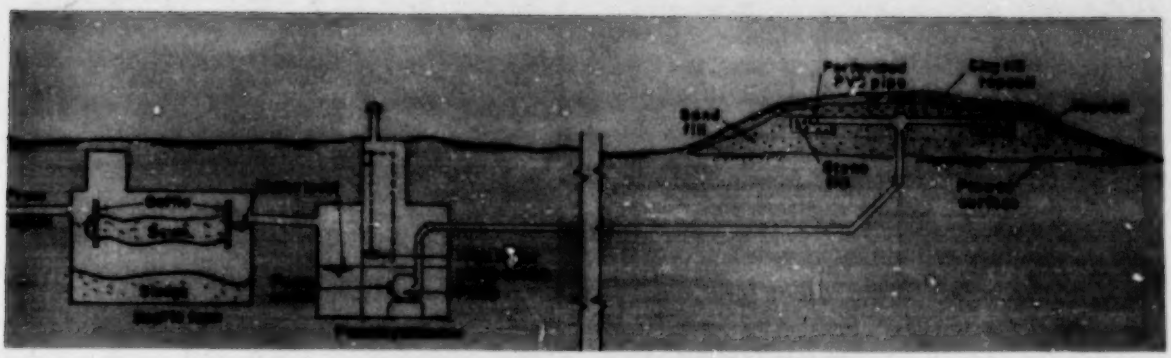

Figure V. Mound system. Mounds are an alternative to subsurface drainage fields when soil percolation rate is above 62 to 70 min/in., water table is less than 3-5' from ground surface, or soil cover of crevice bedrock is less than 5'. Costs for mound system (including septic tank) range from $ 3,000 to $ 4,000; yearly O and M costs are $ 35 - 40/house.

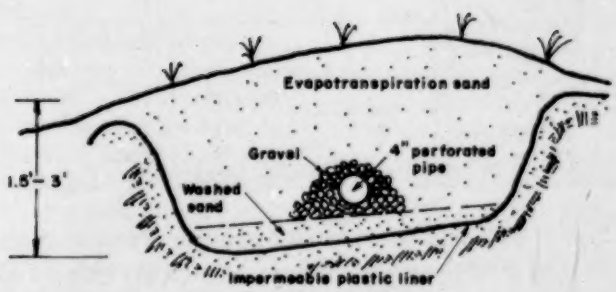

Figure VI. Typical evapotranspiration bed (ET). ET beds combine moisture evaporation from surface and transpiration from plants to dispose of effluent from septic tanks or home aerobic units. Effluent rises through sand. Liner prevents groundwater contamination. Costs (with home aerobic unit) range from $ 4,500 to $ 6,000, with O and M costs of $ 75 - 125/house/year.

cannot be used. Mounds can be used when soil cover is as low as 60 cm.

There are approximately 600 mound systems in Wisconsin and 2,500 in Pennsylvania, built as a result of studies and experiments by the University of Wisconsin's Small Scale Wastewater Project.

The size of the mound depends on size of household and site conditions. For example, a 3-bedroom house on slowly permeable soil requires a mound roughly 20 m long by 15 m wide, with a 90 cm centre height. Most mounds now operating serve single homes, but technically a group of houses could share one mound. The University of Wisconsin is now designing a mound system for a school complex.

Disadvantages of mounds include cost ($3,000 to $4,000, compared with $1,400 to $2,000 for subsurface field) and aesthetics. Some home owners are not pleased to have a mound in the back yard.

The advantages are that mounds last as long and work as efficiently as subsurface fields and are a viable alternative when site conditions do not permit subsurface drainage fields.

Evapotranspiration system

Evapotranspiration (ET) systems combine moisture evaporation from the surface and transpiration by plants. The plastic lined ET bed of gravel and sand accepts and disposes of effluent (see figure VI).

Effluent discharged to the bed rises through sand to the surface where it evaporates or is used by plants. The plastic liner prevents downward liquid penetration and ground-water contamination.

ET applicability is limited because the evaporstion rate of the area must exceed the rainfall rate plus waste water flow. Semi-arid regions in the mid-western and south western United States are best suited to ET.

ET beds are used throughout the south western United States and along the eastern coast. The beds must be carefully installed to avoid puncturing the liner and a layer of sand should be installed under the liner for protection.

Long-term maintenance questions have not been answered for ET beds. One possible problem is salt build-up. It may clog the system cr kill the plants, but beds have not operated long enough to know.

For more information

There is no best sewerage system. The systems discussed here, along with septic tanks and gravity sewers, allow builders and municipalities to choose the system most appropriate for site conditions.

The National Association of Home Builders (NAHB) has published a review of systems entitled *Alternatives to Public Sewers*, which can be obtained from NAHB's Washington office. A comprehensive review of the sewage disposal issue, *Less Costly Wastewater Treatment Systems for Small Communities*, is available from the Environmental Protection Agency, Washington, D.C.

LAND APPLICATION OF WASTE – STATE OF THE ART*

Introduction

The application of treated waste water to land can provide a final high level of pollutant removal. It also provides the opportunity for recycling of nutrients. Land treatment is not *ad hoc* dumping of waste water, hoping that it will somehow purify itself. Land treatment systems must be well planned and designed and carefully managed and monitored to ensure that problems do not develop.

The land application of waste water entails the use of growing plants, the soil surface and the soil matrix for removal of certain waste-water constituents. Sunlight and air make it possible for the plants to grow and the soil to remain aerobic, as well as assist in disinfection and decomposition of organic solids and organisms.

A. TYPES OF LAND TREATMENT

The three types of land application in common usage are: (1) irrigation, (2) overland flow, and (3) rapid infiltration, as schematically represented in figure I. Each can be adapted to different site conditions, can satisfy different objectives, and can produce renovated water of varying quality, depending on design parameters and operation. There are numerous variations and combinations which can be used to optimize the system (1).

1. Irrigation method

The irrigation method is the application of waste water to agricultural lands where a crop is grown. This method can produce an economic return on the crop as well as renovating the waste water. The minimum application is normally enough to satisfy the evapotranspiration of the crops with a 30 per cent excess for deep percolation. However, some installations operate at 2.5 to 3.0 m of application per year, which provides for deep percolation of 80 to 90 per cent of the total amount applied.

The water is subjected to several processes, including physical filtering, adsorption, biological activity and natural uptake, as it percolates down through the soil. A natural disinfection caused by air and sunshine may also occur.

The soil matrix filters out suspended particles in the waste water, and soil bacteria break down the soluble organics and nitrify nitrogen in the waste water. Some of this nitrogen is taken up by the plants, some is stored in the soil, and the remainder is either denitrified (N_2 gas) or percolates downward with the renovated waste water. Soil particles also absorb phosphorus and heavy metals while filtration and adsorption remove bacteria and viruses. Macro-nutrients, nitrogen, phosphorus and potassium, are subjected to uptake by the growing vegetation along with micro-nutrients such as copper, zinc, cadmium and nickel. By reading the fine print on a package of household plant fertilizer, one will note that the same constituents are sometimes coloured and then packaged to sell for the equivalent of several thousand dollars per ton.

This method of land treatment is most widely used. The managers of the Bortnichy State Farm in the Ukrainian Soviet Socialist Republic have found irrigation land treatment very satisfactory. This farm, which serves Kiev, is 16 years old, and has been extensively studied by the Government. The farm is described later in this text (2).

2. Overland flow

Overland flow is the application of waste water to a vegetated slope where the waste water travels along the soil-vegetation interface. The bacteria growing at the interface and on the vegetation treat the waste water in a manner similar to a trickling filter plant. While the treatment mechanism is primarily biological, there is also physical treatment caused by the filtering action of the grass. Waste water also penetrates the top few inches of soil and flows longitudinally through it, and metals, phosphorus and other nutrients are absorbed on soil particles. The growing plants also uptake nitrogen, phosphorus and potassium (3).

With overland flow, application rates often range between 3 and 8 m per year and, therefore, as much as 90 to 95 per cent of the applied waste water can be recaptured for recycling and reuse or discharged to the stream in a near pollutant-free condition.

Overland flow was "invented" in Ohio by a food processing company. It is generally used on very tight soils where there is essentially no downward percolation capacity. Figure II demonstrates how overland flow is related to the other two types of land treatment in terms of soil type.

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* By Kenneth R. Wright, Partner, Wright-McLaughlin Engineers, and President, Wright Water Engineers, and Catherine Kraeger Rovey, Water Resources Engineer, Wright Water Engineers. Reprinted with permission from *Groundwater*, vol. 17, No. 1 (January-February 1979), pp. 47-61. Presented at the Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, 20-22 September 1978. (The introduction was shortened because it dealt specifically with current environmental legislation in the Congress of the United States of America).

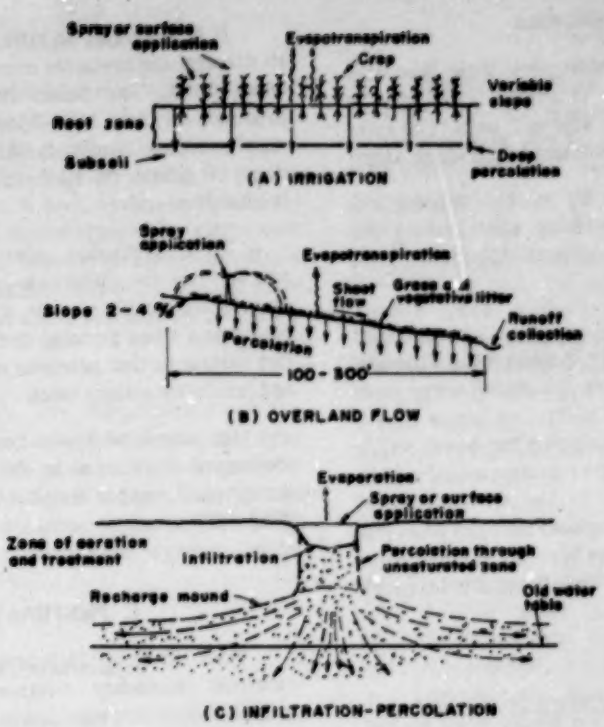

Figure I. Types of land application in common usage

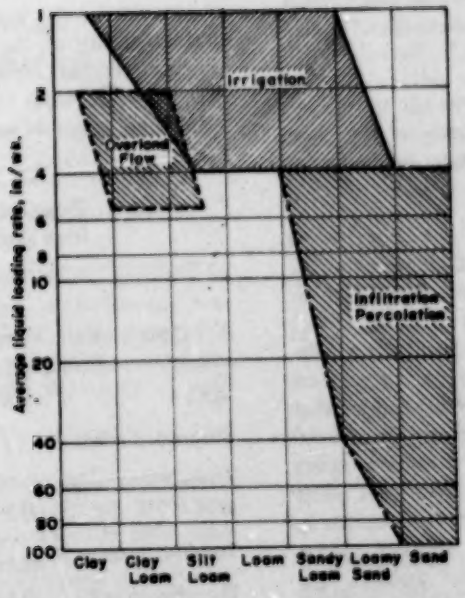

Figure II. Compatibility of land application types with different soils

3. Rapid infiltration

Rapid infiltration requires very little land area and high permeability. The renovated water can be recovered by underdrains or adjacent wells. The main goal of rapid infiltration is treatment of the waste water.

This method operates by merely flooding the grassed surfaces of shallow basins and allowing the waste water to seep into the ground. Application rates range from 30 to 120 m per year (4).

An *ad hoc* rapid infiltration system has been used satisfactorily on the Widefield Aquifer near Colorado Springs for some fifteen years. Municipal water wells are located adjacent to the infiltration ponds. Monitoring of the municipal water supplies has been careful. The water tap foaming problems encountered were from detergent in the days prior to the introduction of biodegradable detergents. Occasional nitrogen problems have been reported. There have been no reported cases of illness related to virus or bacteria transmitted through the aquifer (5).

B. IMPORTANCE OF GROUND WATER

Ground water throughout the world is an important natural resource with high economic value and sociological impact. It is important not only for protecting ground-water aquifers from being polluted beyond maximum levels, but also for enhancing the quality of ground water whenever feasible through proper management.

Alluvial aquifers along streams and rivers have frequently been allowed to degrade as a result of recharge with polluted surface stream water. Degradation of deep ground water has occurred as a result of human activities in aquifer recharge areas.

At Thornton, Colorado, old gravel pits and alluvial wells are used as the main water source for two cities during the winter and as a supplemental source during the summer.

The Thronton well field area lies several miles downstream from the direct surface discharge point for the Denver Metro Sewage Treatment Plant. Late in 1977, an emergency arose as a result of nitrite (NO_2) contamination of the potable water supply being delivered through the distribution system (6). The problem was noticed when a local aquarium owner reported that his fish were dying. Analyses showed that the alluvial aquifer was being recharged with effluent containing 16 mg/l of ammonia nitrogen. The treatment plant was suspected of converting ammonia to toxic nitrite between the well pumping and the delivery to the distribution system. To alleviate the problem, the water wells located immediately adjacent to the surface stream were shut down and a monitoring programming was instituted.

It is important to note that no effort was made to decrease the ammonia concentrations in the effluent discharged to the South Platte River. The City of Brighton, further downstream, derives its municipal supply from the same alluvial aquifer. High concentrations of nitrate (NO_3) have been reported there for at least 20 years.

Wells, infiltration galleries, and floodplain gravel pits are used for withdrawing ground water. An evaluation of the aquifer and its characteristics is of special importance when planning and designing a land application system so that potential problems can be identified and preventive actions taken.

On any land application project, a monitoring programme is essential so that trends in ground-water quality and possible escape of pollutants can be identified early.

C. PRETREATMENT

Prior to land application, waste water usually undergoes secondary treatment. Such treatment is recommended, but with relaxed criteria for suspended solids (7).

The quality of waste water applied to the land varies significantly. For example, in Melbourne, Australia, the waste water receives only primary treatment prior to either irrigation or overland flow. In the Ukrainian SSR, the waste water is given full secondary treatment (8). It is important that waste water not be overtreated prior to land application, not only because of the extra cost involved, but also because too much treatment can remove valuable nutrients. The quality of renovated water is not significantly affected by the organic quality of the water applied, that is, by Biochemical Oxygen Demand (BOD) and suspended solids. The renovated water can generally be expected to fall within the ranges of water quality as shown in table 1.

Table 1. Expected quality of renovated water from land treatment systems

Constituent	*Irrigation*	*Value, mg/l*	
		Infiltration-percolation	*Overland flow*
BOD	1 to 2	2 to 5	5 to 10
Suspended solids	1 to 2	1 to 2	8 to 10
Ammonia nitrogen as N	0.5 to 1	0.5 to 1	0.5 to 1
Total nitrogen as N	2 to 4	10 to 15	2 to 5
Phosphorus as P	0.1 to 0.5	1 to 3	3 to 5

Source: Environmental Protection Agency, *Land Treatment of Municipal Waste-water Effluents* (January 1976).

D. SITE SELECTION

Selection of a suitable land treatment site should involve a thorough investigation of physical characteristics, including soil texture and permeability, underlying geology, topography, and proximity to ground water and surface water. A land treatment site should have the capabilities of transmitting water either over land or through the soil at some desired, controllable rate, and to provide sufficient treatment so that water leaving the site does not cause degradation of the environment.

When evaluating the site characteristics and the related water reclamation capabilities, one should keep in mind that present land application facilities generally do not stress the soil treatment system. Investigations by the Public Works Association Research Foundation indicated that most land application systems provide a large factor of safety (9).

1. Soil characteristics

In most areas, the Soil Conservation Service (SCS) has summaries of physical and chemical properties of soils. Knowledge of these properties is necessary for selecting the optimum land application site and for properly designing the system. Typically, the data provided by SCS include:

(a) Depth to bedrock or gravel;

(b) Depth to seasonal water table;

(c) Permeability of each soil zone;

(d) Sieve analyses;

(e) Permeability of each soil zone;

(f) Available water capacity of each zone;

(g) pH of each soil zone;

(h) Salinity;

(i) Shrink/swell potential; and

(j) Corrosivity.

The depth to ground water should generally be 1.5 m or more to ensure proper renovation and root development. However, if the depth to the water table is less than 1.5 m, artificial water-table control can generally be instituted by using drains or by well pumping.

For rapid infiltration systems, well-drained soils such as sandy clays, sandy loams, loamy sands and gravels are preferred, with depth to water table from 3 to 5 m unless underdrains are used.

Soils with limited permeability such as clays and clay loams are best suited for overland flow systems (10).

2. Geology

Underlying geology is an important consideration in selecting a land treatment site, because it must provide a structural base for the site and, for the irrigation and rapid infiltration methods, a repository or conveyance medium for the treated water leaving the soil zone. Limestone or dolomite areas may be suitable land treatment sites if the soil zone is sufficiently thick and well graded. The pH of the waste water should receive special evaluation when limestone forms the bedrock. Karst areas should generally be avoided because of the potential for sinkhole collapse. Areas underlain by fractured rock can be suitable land treatment sites if the soil overlying the rock is sufficiently thick to prevent piping, which can short-circuit partially treated or untreated water.

3. Topography

A wide variety of topographical conditions can be incorporated into land application sites; however, unusual topography can lessen the application operation and increase costs. For cultivated agriculture, a land surface slope should not exceed approximately 15 per cent. However, when centre pivot sprinkling systems are used, slopes of up to 20 per cent are feasible. Sometimes wooded terrain is used for land application because of the nature of the soil cover. Wooded slopes of up to 30 per cent are suitable. For overland flow systems, slopes of 2 to 8 per cent are satisfactory (11).

4. Proximity to Water

The water table underlying an irrigation site should be deep enough to ensure aerated soil conditions. Generally, 2.5 m is considered adequate. Periodic increases of the water table resulting from irrigation application can bring the water table closer to the surface. In this case, special analyses are required to determine the length of time that the root zone is saturated. With a shallow water table, it is often economical to install underdrains to provide positive water-table control and to provide for easy monitoring of reclaimed water.

Valley bottom land can provide good land treatment sites for all three methods. The frequency and extent of floods should be analysed, but other than for low lands which are frequently flooded (2 to 5 years), floodplain lands often make ideal land treatment sites (12).

The designer should avoid potential short circuiting of waste water directly to surface water, streams or lakes. In many areas, minimum distances from land surface waste disposal sites to surface-water bodies are specified by law.

5. Climate

Waste-water application, except for rapid infiltration, is often restricted to the growing season which is usually defined by that period between the first and last killing frost; however, for pasture, hay and woods irrigation is often beneficial during the months preceding and following the killing frosts.

Warm climates provide special advantages for land treatment. Nevertheless, many successful projects have been operated at northern latitudes. Some rapid infiltration systems operate year-round in cold climates with the waste water being applied under the ice cover, such as at Lake George, New York.

E. PUBLIC HEALTH CONSIDERATIONS

Public health concerns relate to: viruses and pathogenic bacteria; dissolved chemical constituents; crop quality and pollutant uptake potential; and propagation of insects.

Sprayed aerosol droplets have been a concern in the public health field because of their potential to carry viruses long distances under windy conditions.

1. Pathogenic organisms

Pathogenic organisms can survive in the soil and on vegetation for a long time; some have potential lives measured in months. The survival time of organisms outside their natural habitat depends on many factors. Their survival in soil is a relatively unexplored field, though Bouwer and others report a very high degree of virus removal in their Phoenix studies under conditions which would be conducive to virus transmittal (13).

EPA reports that "The effects of working around and handling waste water on land application sites are minimal – the health hazards appear to be no different than for activated sludge and trickling filter plants."

In Melbourne, Australia, the waste-water agency has had several generations of workers directly connected to the Werribee Wastewater Farm (a discussion of the Werribee Farm will follow later in the text). For instance, one top official with the agency was born and grew up on that farm. Both his father and grandfather had been farm workers. Medical records of the present 500 residents of the farm show no special problems with the waste-water farm users. In addition, the absenteeism/sick leave records all indicate normal health for the farm workers, even those who are second or third generation employees of the 28,810-acre farm (14).

Researchers in the Soviet Union report that their public health studies on the Kiev 24,300 ha site showed no public health problems to workers or to consumers, even though 16 per cent of the crop is for direct human consumption, i.e. potatoes (13).

The Scientific Advisory Committee to Governor Lamm of Colorado has reported:

> "Land application treatment of waste water is a viable alternative means to tertiary treatment in Colorado, provided proper site conditions are available. Advantages offered in the synergistic use of water, fertilizer and land resources make the potential for land treatment applications promising and the consideration of the land treatment alternative should be mandatory in waste-water treatment planning. Advantages may also exist, for gravity distribution systems, in lower energy consumption. Land treatment is highly site-specific and the possible range of site conditions within the State is very broad, varying from relatively long growing seasons in plains areas, to extremely short seasons in high mountain locations. Therefore, blanket prescriptions of the technique cannot be made, but each alternative proposal must be separately considered. Further, site specificity not only means that land application treatment might not work for some situations but also that it might be the most well-adapted technique for others. It also means that each community needs to explore a variety of land treatment adaptations before it can say definitely that no viable alternative exists" (15).

2. Heavy metals

The fate of heavy metals in land treatment systems is the item which is often of most concern to the regulatory agencies. For this reason, it is important to evaluate the uncertainties of heavy metals in waste-water effluent following secondary treatment and to analyse the long-term build-up in the soils over a long period of time. Generally one or more of these constituents is more critical than others. Because the soil will remove and store most of the heavy metal concentrations, heavy metal build-up can, in some cases, limit a particular site to a finite number of years of operation. Normal municipal effluent does not contain any significant degree of heavy metals. If they are found in the effluent at levels which are of concern, it is appropriate to trace the contribution back to its source so that pretreatment or recycling of metals can be instituted at that particular source (1).

3. Toxic substances

A well-designed land application system has the capability of removing a high percentage of organic compounds, halogens and carcinogenic materials. With the advent of the Safe Drinking Water Act and its resulting regulations, removal of these materials should receive special evaluation and economic consideration.

4. Macro-nutrients

Nitrogen, phosphorus and potassium are macro-nutrients found in municipal waste water. Land treatment removal efficiencies are indicated in table 2.

Table 2. Expected municipal effluent removal efficiency land treatment system

Constituent	Value, percentage removal		
	Irrigation	Overland flow	Rapid infiltration
BOD	98+	98	80-85
Suspended solids	99	94	99
Total nitrogen as N	85+	80	75-80
Phosphorus as P	99+	40-80	50-60

Source: Cold Regions Research and Engineering Laboratory, waste-water management by disposal on the land (Hanover, New Hampshire, 1972).

Soil has the capability of removing and fixing nearly all potassium and phosphorus contained in the waste water. However, nitrogen is more mobile and, for this reason, the amount of nitrogen applied to the land on an annual basis should receive special evaluation to ensure that the potential concentration of nitrate nitrogen does not result in ground-water contamination. Generally, a nitrate nitrogen limit of 10 mg/l is used as an upper limit in renovated waste water.

F. SLUDGE APPLICATION

Sludge utilization on land for agricultural production is encouraged by Federal law (16). It is considered to be the ultimate disposition of sludge in a manner which will not cause environmental degradation if it is done in a planned and managed way.

The Colorado Department of Health and the State Health Board has now concluded that utilization of stabilized sludge on land for agriculture, silviculture or reclamation purposes is an environmentally acceptable alternative for solving the current sludge problem (17).

Municipal sludge contains the concentrated wastes of the community. Certain components may be toxic and/or hazardous, depending on their concentration and method of application. Such application must not degrade the surface or ground waters. The salt content of sludge can inhibit plant growth if it is applied in high concentrations or at the wrong time. Thus, the key to a proper sludge application project is to have the right quality sludge applied at agronomic rates.

The nominal reason for stabilizing the sludge is to obtain pathogenic destruction, volume and weight reduction, and odour control. Stabilization can be by chemical treatment, digestion, or composting, the most common form being digestion by aerobic or anaerobic means. Stabilization in a lagoon bottom under anaerobic or facultative conditions is a low-cost and effective method.

The Colorado Board of Health allows sludge application without a permit if minimum standards are met relating to nutrient concentration and trace element content. For instance, nitrogen is limited to 60,000 mg/l, zinc to 3,000 mg/l, and cadmium to 30 mg/l. If standards are exceeded, the State reviews and approves on a case-by-case basis.

Colorado recommends subsurface application of sludge as a nitrogen conservation measure. With surface spreading, they estimate that 80 per cent of the ammonia nitrogen may be lost.

Crops should not be fertilized with sludge if they may be eaten raw by humans unless the sludge is first stored for one year. In addition, the Colorado Health Board allows application on ice-covered or frozen land without a permit if the land slope is 5 per cent or less. On land sloping in excess of 5 per cent, annual soil loss must be limited to 5 short tons per acre (11 tons per ha).

To protect the ground water, Colorado requires that the mean annual depth to water table be greater than 2 m and that no domestic well be closer than 45 m. Sludge can be applied in the floodplain as long as it is outside of the area flooded more often than once in 10 years. If these conditions are not met, then special review is needed with issuance of a permit.

Monitoring is required for municipal treatment plants of up to 10 million gallons per day (37,850 m^3/day) with at least one sample taken every three months. For larger plants, sampling every month is required.

G. MONITORING FOR WASTE-WATER APPLICATION

Monitoring of a land application facility is required to ensure that the waste water is being properly renovated and that the environment is being protected. The influent waste water should be analysed in the same manner that conventional waste-water treatment plants are monitored so that the operator knows the specific quality of effluent being applied to the land. In addition, monitoring of the quality of renovated water, the vegetation, and the soils is recommended. This should be considered a part of the management of a land treatment facility.

Renovated water should be analysed for those parameters normally monitored in drinking-water supplies, those required by regulatory agencies, and specific parameters required by the engineer for quality control. Typically, nitrate nitrogen is the parameter most closely monitored.

Crops grown on the land application site should be analysed periodically both to optimize growth and yield and to determine crop intake level of micro- and macro-nutrients.

Soils should be tested periodically (quarterly) for salinity, pH, cation exchange capacity and infrequently (yearly) for considerations of various elements such as heavy metals.

H. CASE STUDIES

1. Bortnichy/Kiev State Farm, USSR(5)

The Bortnichy State Farm outside Kiev, USSR, is a successful land application project. The Minister of Land Reclamation and Water Management in the Ukrainian Soviet Socialist Republic has transmitted a report stating that "since the start of operation of the (waste-water) irrigation system the productivity of agricultural crops has doubled". (Personal communication with N.A. Garkusha of 24 September 1976, transmitting report by A.I. Nasushkin).

The Bortnichy Farm has 24,300 ha under production with irrigation water derived from municipal and industrial waste water generated by Kiev, a city having a population of 1,900,000. The cost of the irrigation system amounted to $US 47,000,000 (32,000,000 roubles) in 1968. Unit cost was $1,940/ha, which included transmission canals, laterals, pumping plants, and all field sprinkler equipment.

Description of the system

The industrial waste-water treatment uses physical-chemical processes at the industrial sources prior to its being combined with the municipal waste water. Approximately 60 per cent of the waste water is derived from industrial sources. Primary treatment consists of screening and pulverizing, followed by settling. The waste water is then routed to the secondary activated sludge plant for aeration and clarification prior to irrigation. The waste water is not disinfected prior to irrigation so as not to waste chlorine or ozone.

The sludge resulting from the primary and secondary treatment operation, which contains 3 per cent solids, is carried by pipeline to sludge drying beds where it is digested using natural processes of sunlight and drying. The USSR Government is currently studying methods of direct application of the wet sludge to the fields. Currently, the dried sludge is used as a field fertilizer with good crop response. Direct application of the 3 per cent solids wet sludge would reduce costs and result in reduced land use for natural drying beds.

Waste water is supplied to 300 irrigation rigs by 32 pumping stations for 24 hours per day. The rigs include the self-propelled power sprinklers DKSh-64, the "Volzhanka", which operate from a closed irrigation system. Irrigation occurs seven months per year, from April to October. The total length of open canals amounts to 41 kilometres with a 1975 flow of 7.2 m^3/sec. During the growing season, 45,200,000 m^3 of treated waste water is used for irrigation. There is no mixing with fresh water. All irrigation is by sprinkler system to maximize efficiency of application. The soil cover in the system is mainly gray or dark gray light clayish loamy podozols.

The various types of crops in the irrigated lands are summarized in table 3. Application rates average 1,500 m^3/ha per season to supplement the natural precipitation of 500 to 580 mm/year. Average temperature during the year is + 7°C. The period with average daily temperatures exceeding 15°C is 115 days. Above-freezing temperatures prevail for 165 to 170 days. The average for the freezing-free period ranges from 19-25 April to 6-10 October.

Table 3. Use of Bortnichy irrigated lands

Crop	*Hectares*	*Acres*	*Percentage*
Cereals	7,300	18,000	30
Potatoes	3,900	9,650	16
Fodder	7,300	18,000	30
Irrigated pasture	3,900	9,650	16
Other crops	1,900	4,700	8
Total	24,300	60,000	100

Environmental effects

Officials of the USSR report no health problems. All effluent is regularly tested and is safe for irrigation. Fourteen years of health records of farm employees have been analysed and no indication has been found that workers are subject to health hazards. The quality of the waste water is constantly controlled by laboratories of various ministries.

The ground-water table ranges from 3 to 16 m in depth below ground surface. By carefully controlling application rates, the recharge to the ground-water table is strictly limited; however, care is exercised to insure against salinity build-up in the soil zone, for salinity increase would be sure to cause damage to the productivity of the soil in this rich agricultural region. The dissolved constituents in the waste water used for irrigation do not exceed 1,000 milligrams per litre.

The objectives of the use of waste water for the Bortnichy State Farms are to increase crop production and to reduce pollution of the Dneiper River which flows through Kiev and which provides environmental and recreational opportunities to the citizens of Kiev and the 49,000,000 residents of the Ukrainian SSR. The Farm is in the vicinity of the Kiev airdrome. It provides a natural buffer against development in the vicinity of the airport, which represents an important benefit.

Macro- and micro-nutrients are provided to the crops by the nutrient-rich waste water. For instance, nitrogen content in the waste water approximates 22 mg/1. The nutrients are furnished to the crops on a periodic basis with each irrigation of approximately 400 m^3/ha.

There is a leaching of salts to the ground-water table, particularly because the water applied has a Total Dissolued Solids (TDS) of 1,000 mg/1. If the Ministry used fresh water (with a salinity of no more than 600 mg/1) the leaching of salts to the ground-water aquifer would be substantially less; however, artificial fertilizers would have to be applied which would tend to add more TDS concentration.

Summary

The Bortnichy State Farm at Kiev is a highly successful waste-water irrigation farm, operated by dedicated and skillful personnel of the Ministry of Land Reclamation and Water Management of the Ukrainian SSR. The project was initiated in 1962 and construction completed in 1968. The favourable economics of the irrigation system using waste-water are evident to USSR officials and to the observer as one views the green fields and busy farmhands going about their work. Crop production has doubled with the use of the waste-water irrigation system. Potatoes for human consumption are grown. Results of careful monitoring of the system and its products show no harmful effects of using waste-water for irrigation.

The economic impact in the Ukrainian SSR is significant in terms of farm income, food production, local employment, and the improved quality of the Dneiper River.

The farm covers 11,660 ha and represents the most productive agricultural land in Australia. The gross returns from the farm's sale of livestock produced approximately $US 1,500,000 in gross revenues in 1974. The farm also provides an essential municipal service by treating waste-water. In addition to cleaning the waste-water, the farm has had a beneficial environmental impact on the area by providing a major wildlife sanctuary. The open space near the metropolitan area discourages urban sprawl in that direction. Many foreign and local visitors tour the farm yearly.

2. Melbourne, Australia: Werribee Farm System(8)

The Werribee Farm of the Melbourne and Metropolitan Board of Works is a highly productive agricultural and livestock enterprise as well as an efficient waste-water treatment project. The farm was constructed in the 1890s and is located only 22 miles from a metropolitan area with a population of 2.5 million people.

Description of the system

Melbourne's sewerage system was established in 1893 and has been in continuous operation since 1896. Raw waste-water is collected from the Melbourne metropolitan area and carried to the Werribee Farm in an open canal. Approximately 20 per cent of these wastes are industrial in nature. The farm currently receives approximately two thirds of the Melbourne area wastes. These wastes have a fifth-day BOD (biochemical oxygen demand) of 600 mg/1. In recent years, the farm has been treating raw wastes at a rate far in excess of its rated capacity. As a result, the Metropolitan Board of Works is currently exploring pretreatment works for the Werribee Farm. The farm has been and will continue to be the pride of the Board of Works. (Interview with A.H. Croxford, Chairman, Melbourne and Metropolitan Board of Works, 7 September 1976.)

Waste-water treatment is accomplished at the farm by three processes. During the irrigation season (6 to 7 months per year), raw sewage is applied to pasture areas totaling 4,190 ha. The applications are intermittent, being approximately 10 cm deep. Between applications, this provides excellent pasture for grazing cattle. Usually a drying-out period of one week is allowed prior to grazing. Approximately one fifth of the total waste-water at the farm is used in this manner. The irrigation operations are continuously controlled by approximately 100 shift workers. The major statistics of the operations are summarized in table 4.

Table 4. Melbourne and Metropolitan Board of Works Werribee Farm System parameters

	Amount	
	Metric	*English*
1974 annual waste-water supply	207,000,000 m^3	168,000 acre-feet
Gross farm area	11,660 ha	28,810 acres
Purification areas	7,210 ha	17,821 acres
Land filtration	4,190 ha	10,351 acres
Grass filtration	1,515 ha	3,744 acres
Lagoons	1,446 ha	3,573 acres
Sedimentation	62 ha	153 acres
Average annual rainfall	49.3 cm	19.4 inches

The waste-water not required for irrigation is treated by sedimentation and oxidation in shallow lagoons. During the winter period, the entire flow is treated by primary settling followed by grass filtration and oxidation pounds. Since permeability is not the key to this particular process, the areas used for this purpose are the heavier clay soils.

Open drains of 1.2 to 1.3 m extend throughout the irrigation area. Their function is to collect surface flows and ground-water seepage for discharge into Port Phillip Bay. Water in the drains is sampled to assure the

proper operation of the waste treatment/irrigation system.

System costs and revenues

The irrigated pastures are grazed by 15,000 head of cattle throughout the year. During the spring and summer, approximately 40,000 to 50,000 sheep are fattened and sold in the fall. About 7,000 cattle are sold annually and replaced with calves born during the year. These operations produce direct revenues for the farm which totalled approximately $US 1,500,000 in 1973/74. The capital investment of $16,800,000 in the farm was amortized long ago. The operation and maintenance costs of the farm are reduced considerably by the revenues which it produces. The costs and revenues are summarized in table 5. The net annual cost of the system is $0.012/$m^3$ of waste-water treated: equivalent costs for treatment by conventional systems would be several times as great. As a result, substantial savings are enjoyed by the people of the Melbourne area because of the farm operations. The over-all benefit-cost ratio does exceed unity.

Table 5. Melbourne and Metropolitan Board of Works Werribee Farm Summary of Costs (1974 Estimates in US dollars)

Construction (initial costs paid off)	
Operation and maintenance	$ 4,044,000
Farm revenues (gross)	$ 1,493,510
Net annual cost	$ 2,549,990
Net annual cost	$ 0.012/m^3

Environmental effects

Since its inception, the farm has had a resident population which has varied from 67 to 500. The health of these people has been similar to that of any other population of the area. No epidemics or disease have occurred, and the livestock on the farm have thrived. There have been some complaints of odour from the farm. These complaints are relatively infrequent and the degree of offense has been minimal. Odour resulted from overloading of the system as the strength and volume of the raw waste-water increased, coupled with occasional management laxness.

The vastness of the farm's operations has provided an open space buffer area for Melbourne. The lagoons at the farm have also developed into an outstanding year-round bird sanctuary. In the summer months, when inland feed and water sources dry up and birds from the northern hemisphere leave their harsh winters behind, the bird population at the farm exceeds 100,000. The farm staff has developed an intense pride in the bird life and welfare. The wildlife sanctuary which the farm provides is an example of how agriculture and waste treatment can work harmoniously with nature.

There have been no reports of ground-water contamination. Application of effluent irrigation has helped provide a fresh-water barrier to the saline water of the adjacent Port Phillip Bay.

3. Muskegon County, Michigan System (8)

The Muskegon County waste-water system has brought 2,266 hectares of previous wasteland into productive irrigated agriculture. The agricultural aspects of the project and the high level of treatment have resulted in an economically productive and environmentally sound project. For each acre-foot (1,233.5 m^3) of irrigation water applied to the land, the regional net benefits amount to $US 62.74. The benefit-cost ratio is currently 1.53:1.00. The annual benefits include direct revenues of $706,000 from sales of corn grain. The annual benefits arising from the basic employment of farm workers are $1,400,000 per year. A savings of $5,716,000 per year is also realized since conventional waste-water treatment facilities which would otherwise have been necessary have not been built.

Substantial secondary benefits include improved aquatic habitat, improved industrial siting potential and general public awareness. Dollar values for these benefits have not been included in this analysis.

Description of the system

Waste-water is collected from 13 municipalities and 5 major industrial sources. Approximately 65 per cent of the wastes currently treated are from industrial sources.

The volume of wastes treated averages 37,267,000 m^3 per year. As the waste collection system is expanded and growth occurs, this volume will increase to approximately 58,000,000 m^3 per year.

Waste-water is pumped approximately 10 miles from the urban centre to the irrigation site through a force main. At the treatment site, the waste-water is first biologically treated. Following this treatment, the waste-water is either applied immediately to the land or stored for later use. All water is chlorinated prior to irrigation as required by State authorities.

The major statistics of the irrigation operation are summarized in table 6. The annual application of waste-water far exceeds the irrigation requirement for corn in this area because the project is a combination waste-water treatment and irrigation project. The over-all economics of the project have, at least in the short term, dictated the high waste-water application rates. The soil at the site is sandy and was considered to be non-productive prior to the waste-water irrigation project. In 1975, the average yield of corn for the waste-water irrigation project was 5.2 m^3/ha. Although this nearly matched the average yield of 5.7 m^3/ha, it is felt that yields of 10.5 m^3/ha may be obtained as

Table 6. Muskegon Waste-Water Irrigation System - Summary of irrigation system parameters

	Amount	
	Metric	*English*
1975 annual waste-water supply	37,267,000 m^3	30,200 acre-feet
Capacity annual waste-water supply	58,000,000 m^3	47,000 acre-feet
1975 usable waste-water supply	37,267,000 m^3	30,200 acre-feet
Gross irrigation site area	3,035 ha	7,500 acres
Usable irrigation site area	2,266 ha	5,600 acres
Average seasonal rainfall (April-October)	49 cm	19.3 inches
Seasonal rate of application	136 cm	4.45 acre-feet/acre
Size rotating irrigation rigs	14-57 ha	35-141 acres
Number of rotating rigs	54	

Table 7. Muskegon Waste-Water Irrigation System-summary of costs

Construction (including land cost)	$37,700,000
Operation and maintenance (1975)	$ 1,822,000
Total annual cost[a]	$ 5,380,000
Total anpual 1975 direct revenues[b]	$ 923,000
Net annual cost[c]	$ 4,457,000
Net annual cost[c]	$0.12/$m^3$ ($0.45/1,000 gal)

a Based upon debt retirement over 20 years at 7 per cent interest.

b Revenues include approximately $216,400 in grants, laboratory services and other miscellaneous revenues.

c After more operational experience is gained, a corn crop yield of 10.5 m^3/ha is estimated. Furthermore, when full design flows of 58,000,000 m^3/yr are realized, net annual costs will increase by about $500,000, resulting in a net annual unit cost of $0.09/$m^3$.

operational experience is gained with the waste-water system.

Ground-water levels at the irrigation site prior to construction varied from less than 1.5 m in most places to 7.6 m. Perforated polyethylene pipe was installed to assure at least 1.5 m of freely draining aerobic soil throughout the site. The drainage network discharges to open channels which carry the clean water to natural waterways. Monitoring of discharge within the site is provided by a network of 272 observation wells scattered throughout the property.

System costs and revenues

The system costs and annual revenues for the Muskegon system are shown in table 7. The cost of construction for the treatment system was $US 37,700,000. The operation and maintenance costs for the system are $1,822,000 per year. Labour costs make up approximately 35 per cent of these annual costs.

The fertilizer value of the waste-water is an important component of the project. It has been estimated that 60 per cent of the nitrogen, 70 per cent of the phosphorus and 100 per cent of the potassium removed from the combined domestic and industrial wastes actually served as fertilizer for the 1975 corn crop. In early 1976, these chemicals were worth more than $190,000 per year.

The irrigation component of the system is the prime source of revenue. In 1975 this amounted to $706,000. In future years, these revenues are expected to increase to approximately $1,400,000 when experience is gained in the operation of the agricultural portions of the system. The capital construction is amortized at 7 per cent over 20 years. After consideration for amortization, operation and maintenance, and direct revenues, the net annual cost of the system is $4,457,000 per year, or $0.12/$m^3$ of water treated. When the system is operating at full capacity, these treatment costs will be reduced to approximtely $0.09/$m^3$. The estimted cost of treating waste-water to a lesser degree by conventional treatment systems in this area is approximately $0.15/$m^3$. When the system is fully developed, an annual savings of $0.07/$m^3$ may be realized.

The costs of agricultural production are similar to those of any other public irrigation project of this magnitude in the area. The only benefit identified under the agricultural category is the revenue received from the sale of the corn grain harvested. The revenues received in 1975 fall short of the potential revenues expected in subsequent years. In the future, these revenues are expected to double, whereas the cost of agricultural production will increase only approximately 20 per cent for the same period. Secondary benefits normally associated with agricultural products were not included in this analysis. A limited special category, however, has been included because it has special meaning for waste-water irrigation projects. This benefit is known as basic employment, as discussed previously.

In the Muskegon system, special efforts were made to convert workers to agricultural employment. These workers represent approximately one third of those employed by the entire system. Using the multiplier factor of 8 for identifying regional national benefits, this results in a net benefit of $1,400,000 per year.

The over-all environmental enhancement of the Muskegon area has been the most visible benefit of the system. To date, three positive environmental impacts have emerged: a general improvement in water quality

in Muskegon County; increased wild-life populations at the irrigation site, and increased aquatic life in Muskegon Lake. These benefits manifest themselves in various forms. Visual improvements in Muskegon Lake's water quality have increased the over-all pride of the local citizenry in their environment, tourist trade, stocking of more sensitive and desirable fish species in the lake and fishing activity, and has created an over-all improvement in the quality of recreational experiences in the area.

The waste-water irrigation system is also viewed by local public officials as an important resource in the improvement of Muskegon County. The improved quality of Muskegon Lake has encouraged the City of Muskegon and private interests to redevelop the lake's waterfront as the focus for downtown redevelopment and community revitalization. Various programmes for attracting industry and over-all economic development of the area stress the capabilities of the waste-water irrigation system.

Monitoring of the ground-water irrigation system at the Muskegon facility shows it to be of high quality with no measurable salinity increase. Pollutants have not degraded the ground-water quality.

4. Sonnenberg-Sterling, Colorado System (9)

The Sonnenberg-Sterling Irrigation Project would use 3,947,700 m^3 per year of waste-water to irrigate 530 hectares of present sand hill prairieland for production of corn grain. This project is small, but the relative economic impact on the region would be substantial. The annual benefits include: (a) cash crop, corn grain production of $US 425,800 per year based on 11.3 m^3/ha yield; (b) basic local employment for farm workers of $140,000; and (c) savings of $479,700 in waste-water treatment which would otherwise be necessary in the Sterling, Colorado area. (This project was first conceived in 1970 with detailed planning commencing in 1975. The project as described herein is a private enterprise system designed as an agricultural enterprise with costs based on economic agricultural construction techniques and actual bids. The project will probably not be constructed as described for institutional reasons. A federally subsidized waste-water irrigation project is anticipated.)

This waste-water irrigation system is unusual in the sense that the financing of the system would be undertaken in a partnership between private interests and government agencies. In this case, the desire to irrigate additional lands is the prime motivating force in the project development. The need to irrigate additional lands, when combined with the waste-water treatment needs in the area, has resulted in the preferred alternative of irrigation with waste-water and achievement of clean water goals.

The first step in the Sterling plan is the collection and transport of the domestic and industrial waste-water flows of the area to a site approximately 4 miles east of the city. At the site, aerated lagoons are used to pretreat the waste-water to avoid nuisance conditions. The nutrient-rich stabilized waste-water is then stored for use as an irrigation and fertilizer supply. Rotating rigs are used to irrigate the crop land.

Description of the system

Included in the system would be wastes from three sources: (a) domestic wastes from the town of Sterling, (b) industrial wastes from the Sterling factory of the Great Western Sugar Company; and (c) industrial wastes from the Sterling, Colorado Beef Company. Industrial wastes represent approximately 60 per cent of the total irrigation supply.

Following biological treatment in the aeration cell, the effluent would be discharged to a storage basin. Since the normal irrigation season lasts only from mid-April to mid-October, it would be necessary to store approximately a six-month volume of waste-water. The storage basin also provides for additional treatment since the solids remaining in the waste-water will settle out. At the time of withdrawal from the basin, the treated waste-waters are disinfected with chlorine prior to irrigation. After accounting for evaporation and minor seepage losses, about 3,580,000 m^3 would be available for irrigation. The irrigation land would consist of about 530 ha in the area of the treatment and storage basins. The waste-water would be distributed for irrigation by 10 circular electric-driven irrigation rigs. Each rig is capable of irrigating 53 ha and could be expanded in the future as needed to include corner systems capable of irrigating an additional 10 ha each.

The primary crop grown would be corn grain for cattle-feeding purposes. Flexibility remains in the design for irrigation of alfalfa, if necessary, by some of the rigs. The soil texture at the irrigation site is sandy. Sprinklers are the only practical method of irrigation; pivot sprinklers are ideally suited for this purpose. The design application rate is 67.5 cm per year.

The use of sewage effluent assures that nitrogen would be applied frequently and in small amounts. Allowing for some loss of nutrients, about 280 kg/ha of nitrogen and 67 kg/ha of phosphorus would be applied. Unknown quantities of trace elements would also provide fertilizer value to irrigation water. The expected initial yields of the system are 11.3 m^3/ha. As the organic content of the soil increases through waste-water application and the plowing in of sludges collected in the storage basins, the expected yields would increase to the 13 m^3/ha range.

The major parameters of the irrigation portion of the Sonnenberg-Sterling system are summarized in table 8.

The soils of the area are well drained with ground-water 25 m or more below the surface. The natural

Table 8. Summary of irrigation system parameters - Sonnenberg-Sterling Waste-water Irrigation System

Item	Amount	
	Metric	English
Annual waste-water supply	3,947,700 m^3	3,200 acre-feet
Usable waste-water supply	3,580,000 m^3	2,900 acre-feet
Gross irrigation site area	688 ha	1,700 acres
Usable irrigation site area	530 ha	1,310 acres
Average seasonal rainfall (15 April-15 October)	30.5 cm	12.0 inches
Seasonal rate of application	67.5 cm	26.6 inches
Size rotating irrigation rigs	53 ha	131 acres
Number of rotating rigs	10	

drainage characteristics of the site would allow ample movement of the percolated water to the South Platte River approximately 5 km to the north.

System costs and revenues

The estimated total construction cost of the Sonnenberg-Sterling system is estimated at $2,441,000. The annual operation and maintenance costs of the system are estimated to be $271,000.

The projected annual revenue for the waste-water irrigation system would develop only in the irrigation component. These revenues develop from the sale of the corn crop harvested. Based on a projected initial yield of 11.3 m^3/ha, these revenues would total $425,800 per year, but would vary depending upon actual yields of the system and the prevailing market prices. As experience is gained in the operation of the system and the organic content of the soil improves, a general upward trend in these revenues can be expected.

The costs and revenues of the Sonnenberg-Sterling system are summarized in table 9. Capital construction costs are amortized at an interest rate of 7 per cent over a 20-year pay-back period. Financing of the capital construction costs is anticipated to be through industrial revenue bonds. If other methods of financing were available via municipal bounds or federal funding at lower interest rates, lower annual costs could be achieved.

After consideration is made of the direct revenues produced by the sale of corn, the net annual costs of the system would be $75,200 per year. This represents a cost of $0.02/$m^3$ of waste-water treated. For comparative purposes, a conventional system which would provide similar water quality in the same area would be approximately $0.12/$m^3$. Thus, an initial savings of $0.10 per m^3 of waste-water treated would be realized immediately.

Table 9. Sterling-Sonnenberg System-summary of costs

Construction	$ 2,441,000	
Operation and maintenance	$ 271,000	
Total annual cost	$ 501,000	
Total annual direct revenues	$ 425,800	
Net annual cost	$ 75,200	
Net annual cost	$ 0.02/m^3	($0.07/1,000 gal)

The designation of benefits has been divided into four general categories. The waste-water treatment costs are those involved in the transport to, and pretreatment of, the wastes at the irrigation site. Since the storage basin provides treatment in addition to storing flows during the winter non-irrigation season, half of the construction cost ($303,100) was allocated to agricultural production. The regional benefit of $479,700 assigned to waste-water treatment is the estimated cost of providing treatment by a more conventional alternative. This benefit can vary substantially depending upon local stream quality problems. In the Sterling area sulphates and nitrogen are emerging problems in the water supplies. The estimated equivalent treatment cost includes provision for nitrogen removal only.

The cost of conventional treatment is considered a benefit to the Sonnenberg system since it represents a regional investment which would be necessary in the absence of the waste-water irrigation project.

Additional benefits for over-all environmental enhancement, such as water recreation and wild-life habitat, have not been quantified.

The annual cost of agricultural production includes provision for harvest machinery, supplemental fertilizers and herbicides, irrigation equipment, etc. The benefits identified with agricultural production include only the direct revenues associated with the sale of the corn crop. They do not include the secondary regional benefits sometimes associated with the sale of agricultural products, which typically range in the order of 50 per cent of the direct revenues. The benefits also do not include intangibles such as the enhancement of local cattle feed supplies for local feed lots, nor the development of a firm irrigation water supply.

Summary

Due to the law passed by Congress recently, the rules and regulations of the Environmental Protection Agency, and the need to optimize federal funding, it

is necessary to consider land treatment when planning and designing new sewage treatment facilities. Items to be weighed in determining the appropriateness of choosing a land treatment approach include site characteristics such as soil conditions, geology, topography, proximity to water, and climate. If the land treatment approach is within 15 per cent of being the most cost effective, it will probably be selected. The decision must be made as to which method to use: irrigation, overland flow, or rapid infiltration. An evaluation must also be made of the aquifers and their properties so that potential problems can be identified and appropriate preventative action taken.

A monitoring programme is essential for land treatment systems so that awareness is maintained as to the actual quality of effluent being produced and the first indications of potential effects on ground and surface waters, crops and soils.

The application of treated waste-water to land can provide an economical and environmentally viable alternative to conventional waste-water treatment.

References

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(10) C.W. Thornwaite Associates, "An evaluation of cannery waste disposal by over-all flow spray irrigation – Campbell Soup Co., Paris Plant".

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(13) Bouwer and others, *Waste-water Renovation and Reuse: Virus Removal by Soil Filtration.*

(14) Personal conversation between the author and Mr. R.H. Engelsman, Secretary, Melbourne Metropolitan Board of Works, Melbourne, Australia.

(15) Report of the Task Force on the Land Application Treatment of Waste Water to the Governor's Science and Technology Advisory Committee.

(16) The Federal Water Pollution Control Act Amendments of 1972, PL 92-500.

(17) *Guidelines for Sludge Utilization on Land*, technical policy prepared by the State of Colorado Department of Health.

SELECTIVE INFORMATION SECTION*

* Most of the abstracts reproduced below are from the Selected Water Resources Abstracts of the Water Resources Scientific Information Center, Office of Water Research and Technology, United States Department of the Interior, for which acknowledgement is hereby gratefully recorded.

Subject	*Source*	*Description*
Conservation in agriculture	P.J. Rathwell and R.F. Leyden, "Cost comparison of drip and flood irrigations systems", *Journal of the Rio Grande Valley Horticultural Society*, vol. 30 (1976), pp. 79-86	Drip irrigation and conventional surface flood irrigation for citrus orchards are compared with respect to installation and operating costs. Observations were made at an experimental citrus centre in the Lower Rio Grande Valley of Texas. The results are presented. Drip irrigation provides a substantial savings of water in newly planted orchards, but as trees grow, water requirements are about the same under either drip or flood irrigation. The investment costs are comparable for both systems. The savings associated with a drip system are achieved during the first years of an orchard's existence. The labour involved in maintaining and cleaning the drip system is likely to be comparable to the irrigation labour required in a levelled orchard. Electrical costs may run high if the drip system is not engineered to deliver the required amount of water at a minimum electrical usage.
Conservation in agriculture	G.D. Thompson, "Irrigation of sugar cane", *South African Sugar Journal*, vol. 61, No. 3 (March 1977), pp. 126-131	The purpose of this review is to collate the pertinent available information, to assess the adequacy of the present state of knowledge, and to indicate the aspects of irrigation research that appear to most warrant further investigation. Within the South African sugar belt it is possible to discriminate between areas where irrigation is used to increase yields obtainable under rainfed conditions, and areas where irrigation is necessary to guarantee continuous sugarcane production. It has become traditional to refer to the former as areas requiring "supplementary" irrigation, and to the latter as requiring "total" irrigation. The decision to install a supplementary irrigation scheme in the rainfed areas is unfortunately seldom an easy one to make. Capital and running costs in relation to the value of the extra cane produced have always been such that profitability has been marginal, and most of the schemes which have remained in operation have been on miller-cum-planter estates where milling profits can be used to make irrigation more worth while, and on fields as close as possible to the mill itself so that transport costs for the increased crop can be kept to a minimum.
Cost sharing	R.M. North and W.P. Neely, "A model for achieving consistency for cost sharing in water resources programmes", *Water Resources Bulletin*, vol. 13, No. 5 (October 1977), pp. 995-1005	Three basic principles of responsibility have influenced the Federal/non-Federal cost-sharing rates for water resources programmes: (1) full payment by beneficiaries; (2) exclusive Federal assumption of costs; and (3) joint Federal/non-Federal sharing. The efforts to determine appropriate cost-sharing rates have resulted in several hundred complex arrangements involving contributions, user charges and direct sales based on many variations of payment terms. This is expressed in a basic present value model developed to determine the non-Federal water resources programmes and projects for both implementation and operation, maintenance and repair (OMR) stages. The model introduces the concept of a composite (implementation plus OMR) cost share as a focus for developing appropriate resources investments. The model can be used as a focus for policy decisions on cost-sharing which seek to

Subject	*Source*	*Description*
		achieve consistent and equitable cost-shares for the purposes provided while maintaining an efficient allocation of resources within water programmes.
Data acquisition	P.A. Castruccio, H.L. Loats, T.R. Fowler, and P. Robinson, "User requirements and user acceptance of current and next-generation satellite mission and sensor complement, oriented toward the monitoring of water resources", National Technical Information Service, Springfield, VA 22161 (No. N76-1552, 15 December 1975)	Principal water resources users were surveyed to determine the applicability of remotely sensed data to the user's present and future requirements. Analysis of responses was used to assess the levels of adequacy of LANDSAT 1 and 2 in fulfilling hydrological functions and to derive systems specifications for future water resources-oriented remote sensing satellite systems. The analysis indicated that water resources applications for all but the very large users require: resolutions of the order of 15 metres; number of radiometric levels of the same order as currently used in LANDSAT 1 (64); number of spectral bands not in excess of those used in LANDSAT 1 (4); and repetition frequency of the order of two weeks. The users had little feel for the value of new sensors: thermal IR, passive and active microwaves. What is needed in this area is to achieve specific demonstrations of the utility of these sensors and submit the results to the users to evince their judgement. All users indicate that the most significant information requirements are in the area of better knowledge of the characteristics of precipitation, specifically, the temporal behaviour (intensity versus time) of rainfall, its areal distribution, the statistics of succession of rain events as a function of time, and the storm travel characteristics.
Data acquisition	R.A. Sutherland and J.F. Bartholic, "Significance of vegetation in interpreting thermal radiation from a terrestrial surface", *Journal of Applied Meteorology*, vol. 16, No. 8 (August 1977), pp. 759-763	The regions between crop rows were modelled as infinitely long diffuse cavities. Geometrical view factors were calculated, accounting for reflected radiation emanating internal to the cavity and from the background sky. A "cavity" emissivity dependent on local geometry was defined to allow for correcting apparent temperatures to true temperatures. The total emissivity appropriate for correcting aircraft thermal data was calculated then by averaging all emissivity components to account for soil, crop and background. It was shown that even for the lowest crop and vegetation emissivity is greatly increased, giving rise to a decreased error in remotely sensed temperature data.
Ecological impact of water development	J.A. Diemer and N. Wengert, "Water for energy: an approach to comprehensive impact assessment", *Water Resources Bulletin*, vol. 13, No. 5 (October 1977), pp. 885-893	The effects of energy development on the water resources of the Colorado River and Great Basin regions are expected to be substantial. Complex physical, economic and institutional interactions may be expected. Most research on these impacts appears single-purpose, fragmented, unco-ordinated, and often inaccessible to potential users, particularly to those with responsibility for energy/water policy and programme decisions. A comprehensive, integrative framework for assessing alternative water allocation decisions is outlined, with a heuristic decision-making model for evaluating impacts on maximization of gross (or net) regional product and regional social welfare, and for assessing the region's contribution to national economic objectives. The suggested model provides a structure for application and

Subject	*Source*	*Description*
		integration of data of various kinds to a range of situations arising from possible impacts from energy proposals. The focus is on water/energy relationships but the model may provide a framework for comprehensive analysis of a variety of environmental actions and resulting system perturbations and effects.
Ecological impact of water development	R.J. Pitchford and P.S. Visser, "The effect of large dams on river water temperature below the dams, with special reference to Bilharzia and the Verwoerd Dam", *South African Journal of Science*, vol. 71 (July 1975), pp. 212-213	The majority of large dams are constructed in such a way that the normal water outflow from them into the rivers below is from sluices below the water surface level of the dam. Depending on the depth below surface level, temperatures of the outflowing water might be very different from the normal water temperatures existing in comparatively shallow rivers. The effect of water temperature changes on fauna and flora ecology below the dam might be apparent for long distances downstream. Water temperature plays a vital role in Schistosome transmission (1) in permitting a suitable snail population to flourish and (2) in controlling the length of the incubation period of the parasite in the snail. Numerous situations might therefore arise which could alleviate or aggravate either the snail or the parasite population, or both, as a result of a permanent change in water temperature over large areas. Possible changes in the Orange and Fish Rivers due to the existence of the Verwoerd Dam are studied.
Ecological impact of water development	Q.D. Stephen-Hassard and E.M. Grabbe, "Hawaii and the Manganese nodule industry", *'Oceans '77'*, Proceedings of the Third Annual Conference held at Los Angeles, California, 17-19 October 1977, vol. 2 (1977)	The State of Hawaii is located near the centre of rich manganese nodule deposits containing nickel, copper and cobalt of commercial value. The State has followed the early research, exploration and pilot mining activities of various companies and late in 1976 began a project to determine the economic feasibility and the socio-economic and environmental impacts of establishing a manganese nodule industry in Hawaii. The project will address the concerns of the people of Hawaii in these impact areas and will recommend a course of action. The University of Hawaii has been engaged in research, exploration, deep ocean mining tests and ocean environmental studies of manganese nodules during the past decade. The common interests of the State, the University of Hawaii and industry have led to several joint assessments. The project includes the following tasks: economic impact assessment, analysis of ocean transportation systems, analysis of processing systems, physical criteria and description of processing activities, metals extraction process chemistry, manpower supply and training, environmental law analysis, environmental evaluation, and waste disposal on land and agricultural potential of manganese nodule tailings.
Ecological impact of water development	M.L. Warner, J.L. Moore, S. Chatterjee, D.C. Cooper and C. Ifeadi, "An assessment methodology for the environmental impact of water resource projects", National Technical Information	This report presents technical materials intended for use in reviewing environmental impact statements (EIS) on major reservoir construction projects. Methods and materials for determining the completeness and accuracy of EIS are discussed, with special emphasis on water quality and ecological impacts. The report contains six

Subject	Source	Description
	Service, Springfield VA 22161, (No. PB-240 002, July 1974)	related but individually referenced discussions that address: (1) reservoir project planning, construction, and operation activities; (2) water quality impacts of reservoir construction; (3) ecological impacts of reservoir construction; (4) economic, social and aesthetic impacts of reservoir construction; (5) review criteria for assessing general statement completeness and accuracy; and (6) a review of impact assessment methodologies. Important issues or potential impacts that might be found in an adequate EIS are presented. In addition, the water quality and ecological impacts sections discuss the site-specific conditions under which a given potential impact may or may not occur. The section on water quality impacts also presents a detailed comparison of mathematical models for predicting impacts on water temperature, dissolved oxygen levels, and some chemical constituents of surface waters. The sections dealing with water quality, ecological, and economic-social-aesthetic impacts include extensive citations of relevant literature. This study is applicable to the full range of environmental conditions in which reservoirs may be constructed.
Effects of pollution	R. Engle, "Relationship of marine pollution to human health", *Proceedings of the International Symposium on Marine Pollution Research*, held at Gulf Breeze, Florida, 27-29 January 1976 (Environmental Protection Agency, Office of Research and Development Report No. EPA-600/9-76-032, January 1976)	Some toxic substances, carcinogenic compounds or biological agents are concentrated in invertebrates and lower vertebrates, suggesting the possibility that these compounds could be transferred through the food chain to humans. A good example of biological magnification occurred when Japanese fishermen developed mercury poisoning from consuming fish from Minamata Bay. Superior methods must be developed to screen new chemicals for toxicity, especially since less than one half of the new chemicals that go into major production are screened for carcinogenicity. The development of marine biomedicine will not be realized unless biomedical scientists, knowledgeable about human health problems, learn more about marine biology. Similarly marine biologists knowledgeable about the great variety of creatures of the sea must learn more about biomedical problems and needs. Both will suffer if scientists fail to initiate integrated studies of the marine biota and human health.
Effects of pollution	C.C. Coutant, "Thermal effects on fish ecology", *Encyclopedia of Environmental Engineering*, vol. 2 (W. and G. Baird Ltd., Northern Ireland, 1976), pp. 891-896	A general review of the present knowledge of the thermal effects on fish ecology is presented which includes information on temperature as a lethal agent, as a stressing factor, as a controlling factor, as a limiting factor, as a masking factor and as a directing agent. It is concluded that temperature is probably the preeminent master factor in the lives of fish and that no study of fish ecology would be meaningful without consideration of thermal relationships. It is said that while, within limits, fish possess effective machanisms for adapting to thermal changes, man must be careful not to exceed these limits if he wishes to preserve a productive commercial and recreational fishery.

Subject	*Source*	*Description*
Erosion and sedimentation	S.S. Baydin, "Possible effect of sediments and channel processes on run-off redistrubution in a river delta", *Soviet Hydrology*, Selected Papers, No. 4 (1975), pp. 234-242	All channel forms in the mouths of rivers are associated with types of bed-load transport produced by the energy of the flow. Therefore, when investigating channel processes one should proceed from the energy characteristics of flow and the types of bed-load movements and not from the forms of channel formations and geomorphological relations. In this case, the initial data must include: flow, the particle size of bottom deposits and sediment concentration, the slope of the land (valley) and its ratio to the slope of the water surface, and the ratio between the water slope during the flood and low-flow periods. A stream with a high flow energy does not meander and selects the shortest and straightest direction. Sediment transport is achieved in these reaches in the smooth stage during flood rise and in the structural bottom stage during flood recession and the low-flow period. With a decrease in slope and when flow energy is inconsistent with the particle size of the sediment, the flow can successively concentrate its energy in individual reaches, periodically moving the sediments from one reach to the other in the course of the year. The main types of structural sediment movement are: ribbon dune (riffle), midstream bar and side bar; and of structureless movement, continuous traction and sliding.
Erosion and sedimentation	R.F. Luque, "Erosion and transport of bed-load sediment", National Technical Information Service, Springfield, VA 22161 (No. N75-27298, 1974)	The results were presented of a series of experiments in which were measured: the mean critical bed-shear stress at SHIELDS' grain-movement condition and at the intiation of non-ceasing scour, the rate of bed-load transport, the average particle velocity, the rate of deposition, and the average length of individual steps of saltating bed-load particles, in water, as a function of the time-mean bed-shear stress. These experiments were performed in a closed rectangular flow channel at different slopes of the bed surface and using five different bed materials (two sands, gravel, magnetite and walnut grains). A comparison of the threshold drag acting at different downward slopes of the bed surface (0, 12, 18 and 22 degrees) resulted in a surprisingly large critical-drag angle of 47 degrees. The initiation of non-ceasing scour of a loose granular bed was studied experimentally behind a consolidated bed of the same material as the loose bed. The corresponding instantaneous threshold drag was about three times larger than the threshold drag acting at SHIELDS' grain movement condition. The rate of bed-load transport measured as a function of the mean bed-shear stress satisfied a generalized MEYER-PETER and MULLER formula (1948), also at various downward slopes of the bed surface, as investigated up to 22 degrees. The rate of particle deposition was proportional to the rate of bed-load transport, and the average length of individual particle steps was a constant. This implied that the probability of a bed-load particle being deposited when striking the bed surface was independent of the flow rate within the experimental range.

Subject	*Source*	*Description*
Evaluation process	G.L. Bultena, D.L. Rogers and K.A. Conner, "Characteristics and correlates of public knowledge about a water resource development issue", Ames, Iowa State University Department of Sociology and Anthropology, 1975	Public knowledge about an environmental (reservoir) project proposed by the Army Corps of Engineers was examined. The study objectives were: (1) to determine how knowledgeable local citizens were about the proposed reservoir, for the purpose of assessing their ability to respond meaningfully to the Corps' proposal, and (2) to test the importance of several variables which were hypothesized as affecting knowledge of environmental issues including, social class, age, personal attitudes, perceptions of likely impacts of a reservoir and amount of social interaction and group involvement of persons regarding community issues. Although the project proposal had become a prominent local issue, a relatively low level of public knowledge about the reservoir existed. As hypothesized, the best informed persons were those who were (1) younger in age, (2) of higher socio-economic status, (3) more strongly opinionated on environmental issues, (4) more convinced of the efficiacy of citizen actions in public affairs, (5) more conscious of likely community impacts of a reservoir, and (6) most often convinced that they were benefactors, rather than beneficiaries, of the project. The strongest explanatory variable for such knowledge was extensive previous political involvement in activities designed to influence agency decision making. Respondents who were receiving the greatest personal benefits from a reservoir were no better informed about the project than those who were anticipating few, if any, benefits. Relatively few respondents perceived themselves as deriving personal benefits from the reservoir.
Evaluation process	G.L. Bultena and D.L. Rogers, "Studies of public preferences and group interactions to guide land-use planning and control", Report presented at the Iowa State University Faculty Symposium on Land-Use Planning and Control, 1973	The role of citizen involvement in future land-use planning is discussed. An organizational-expertise decision-making model is characterized by a division of complex activities into smaller operations: these operations are performed by sub-units comprising specialists. Advantages and limitations of the model are detailed. An alternative model, the democratic-participatory model, seeks expanded citizen involvement in public environmental programmes; administration is structured so as to optimize input from citizens. Approaches to public participation, including public hearings, citizen advisory panels and public opinion polls, are outlined. The power relationships between agencies and interest groups are analysed; the need for cohesive organized group efforts by public interest groups is stressed. A brief historical perspective of public sentiment toward and citizen's priorities in the management of resources is presented.
Evaluation process	J.F. Timmons, "Guidelines for developing state and national public land-use policies", Report presented at the Conference "Toward an Effective Land Use Policy for Michigan", Kellogg	Guidelines for the development of state and public land-use policies are presented. Subjects include: (1) the need for land-use policies resulting from current land use and environmental problems; (2) the nature and scope of land-use policy and its objectives; (3) recommended shifts toward state initiatives in developing

Subject	*Source*	*Description*
	Center, Michigan State University, East Lansing, Michigan, 17 May 1973.	land-use policy; (4) recommended shifts in the control of land resources – from public interest; and (5) suggested guidelines for developing land-use policies as a continuing process. The interrelationships between land use, environmental quality, and public interest goals are emphasized. Land-use policy development procedures should include: (1) a statement and analysis of goals, economic impact and trade-offs; (2) provisions of flexibility in regulation and compliance contingent upon an area's regional problems or peculiarities; (3) encouragement of experimentation, innovation and applied research; (4) evaluation of ongoing programmes; (5) room for citizen participation in planning and implementation; (6) efficient and effective means of bringing each level of government into land-use policy, planning, programming, and performance; (7) financial incentives; (8) consideration of all current and potential uses of natural resources and their environmental effects, and (9) analysis of the impact of technological advances.
General	P.A. Castruccio, H.I. Loats, Jr. and T.R. Fowler, "The application of remote sensing to the development and formulation of hydrologic planning models", National Technical Information Service, Springfield VA 22161 (No. N76-18633, January 1976)	The launch of LANDSAT has provided water resources managers and hydrologists with broad prospects for efficient acquisition of essentially real-time data. The reduction of satellite data to practical, operational information requires a clear, easily applicable methodology for converting these data into quantitative hydrologic parameters. Summarized is the development of a model specifically structured to take full advantage of the capabilities of LANDSAT, e.g. its frequent recurrence and consequent ability to determine seasonal variations in a watershed's conditions. The effort was structured along two major routes: (1) the development of a hydrologic planning model specifically based upon remotely sensed inputs, including its test and verification from existing records: and (2) the application of LANDSAT data to supplying the model's quantitative parameters and coefficients. This first phase of the effort focused on the definition of the "drivers" – those hydrologic processes to which peak runoff is most sensitive – upon the synthesis of a simple yet effective model for the estimation of long-recurrence outflows. Next, this report describes in detail the study's second phase, which includes the development of a routing model for use in sensitivity analyses and a quantitative investigation of the accuracy and completeness of the hydrologic information which can be extracted from remotely sensed imagery.
Groundwater management	H. Meisler, "Summary of ground-water conditions in the Jaffna Peninsula, Republic of Sri Lanka, with a plan for investigating the feasibility of ground-water development", Geological Survey, Trenton, N.J. Water Resources Division, 1977	Ground water in the Jaffna Peninsula of Sri Lanka occurs within solution openings of the Jaffna Limestone of Miocene age. The fresh-water forms a complex of lenses up to 25 metres thick overlying saline water derived from the sea. Salt-water intrusion and upconing of the salt water has occurred at several locations primarily along the coast. Recharge to the aquifer occurs during October-December. Discharge is primarily to wells and to springs along the north coast. Spring discharge is small compared with withdrawal from wells. Pumping from wells in an intensively studied 142

Subject	*Source*	*Description*
		square kilometre area of the Peninsula was 55.5 million cubic metres in 1976, whereas discharge to visible springs was an estimated 9.3 million cubic metres. Pumping during January-September removes water from storage, causing heads to decline and the salt water-fresh-water interface to rise. The storage is replenished as heads increase and the interface is depressed during the following October-December. Consequently, most of the recharge goes into storage rather than discharging to the sea.
Identification of pollutants	Environmental Protection Agency, "Introduction to instrumental analysis of water pollutants: training manual", National Technical Information Service, Springfield, VA.22161 (No. PB-261 318, November 1976)	A training manual is presented as an accompaniment to EPA National Training Center Course 107.1, "Introduction to instrumental analysis of water pollutants." It includes the principles utilized, basic design, analytical applications, operational procedures and quality control aspects for each of the instruments most commonly used in water analysis. The instruments described are: pH meter, conductivity meter, dissolved oxygen probe, colorimeter, flame photometer, infrared spectrophotometer, atomic absorption spectrophotometer, turbidimeter, total organic carbon analyzer and gas chromatograph.
Identification of pollutants	E.D. Goldberg, "Global monitoring of marine pollutants", in *Proceedings of the International Symposium on Marine Pollution Research* held at Gulf Breeze, Florida, 27-29 January 1976 (Environmental Protection Agency Report No. EPA-60019-76-032, January 1976)	There are several compelling reasons for initiating a a continuing and systematic surveillance of already defined pollutants in coastal marine waters. First, the present exposure levels to marine organisms can be used in principle by ecologists to ascertain whether any organisms or communities of organisms are threatened. Second, environmental concentrations allow an assessment of danger to public health through the consumption of sea foods. Third, present levels allow predictions of future levels. With knowledge of present and past environmental releases of the pollutant in question and with an estimate of future leakages based upon production and use, data models for pollutant dispersion about the environment can be formulated and future levels may be foretold. Such information is vital to those responsible for management of marine resources. Where predicted levels are unacceptable on the basis of possible environmental impact, restrictions upon releases can then be imposed. There are four collectives of pollutants that may jeopardize continued use of marine resources: artificial radionuclides; petroleum hydrocarbons; chlorinated hydrocarbons; and heavy metals.
Network design	W.G. Hines, D.A. Rickert and S.W. McKenzie, "Hydrologic analysis and river-quality data programs", *Journal of the Water Pollution Control Federation*, 49, No. 9 (September 1977), pp. 2031-2041	A unified approach is described for the collection of river-quality data. River-quality sampling and analysis programmes can be dramatically improved through a de-emphasis of the routine monitoring approach and added emphasis on the following: (1) a competent analysis of the natural and man-controlled aspects of river hydrology as reflected by streamflow and water-temperature pattern and channel morphology; (2) the re-analysis of existing quality data, after their segregation into compatible temporal and spatial units, as derived from the hydrologic analysis; and (3) the use of

Subject	*Source*	*Description*
		repetitive synoptic studies tailored to the environmental conditions and problems of interest in each river basin.
Precipitation	J. Medhi, "A Markov chain model for the occurrences of dry and wet days", *Geophysics*, vol. 27, No. 4 (October 1976), pp. 431-435	Study of rainfall data in India began as early as 1899 with the work of Blanford. His work was extended by Sir Gilbert Walker. Mahalanobis, in his classic work *Sankhya, V* (1940), pp. 1-20, broke entirely new ground with sound statistical reasoning in his study of the rainfall, runoff and other meteorological features of the river basins of Orissa. Models based on stochastic processes and time series are now being applied in meteorological studies. Gabriel and Neumann used a Markov chain model in a study of weather conditions in Tel Aviv. A similar Markov chain model was used for the occurrence of dry and wet days in Gauhati (Airport) and to test the statistical significance of the model.
Precipitation	M.L. Shelton, "The 1976 and 1977 drought in California: extent and severity", *Weatherwise*, vol. 30, No. 4 (August 1977), pp. 139-146	Many stations in California experienced their most severe drought of this century during the 1976 and 1977 precipitation years. The unseasonable dry weather adversely affected agriculture, recreation, and water supplies throughout the State. During 1976, agriculture and the ski industry experienced large financial losses because precipitation was insufficient to support normal activities; range and forest fires burned approximately 165,000 acres of dry vegetation; and an acute water shortage in Marin County prompted one city to discourage tourists. The impact of the drought probably would have been even greater, but the state-wide system of water shortage and transfer was able to compensate for natural water shortages by providing water to many affected areas. Moisture deficits at the seven stations selected as representative of various climatic regions in California indicate that the 1976 drought was more severe at a majority of these sites than the record dry year drought of 1924. Only the south coastal area represented by Los Angeles experienced a more severe drought during 1924 than during 1976. The state-wide drought pattern suggested by the data for the representative stations is that the 1976 drought appeared in the State earlier than the 1924 drought, but it spread throughout the State more slowly than the 1924 drought.
Precipitation	N. Tripathi, "Influence of certain factors on rainfall frequency values", *Indian Journal of Meteorology, Hydrology and Geophysics*, vol. 27, No. 4 (October 1976), pp. 423-430	Based on 84-year data of Calcutta, Delhi, Bombay, and Madras, it was found that to estimate the maximum one-day point rainfall for long return periods, more reliance is to be placed on stations with the longest records. For the error to be within plus or minus 25 per cent in about 80 per cent of cases, in the estimation of return period values, extrapolation may be made to five times the period of record and to ten times the period of record if the outliers are excluded from the series. Criteria to find the outliers were suggested. Some evidence was found to show that the return period values of rainfall of a station increase in air pollution at that station.

Subject	*Source*	*Description*
Sources of pollution	G.J. Kelly, "Ground-water quality and corrosion: the Australian scene", in *Groundwater Quality – Measurement, Prediction and Protection*, Proceedings of the Water Resources Centre Conference, 6-8 September 1976, Berks, England, University of Reading, 1976	The general aridity of the Australian continent make its ground-water resources especially valuable and heavily used for water supply. Increasing concern by pump owners about unsatisfactory and unpredictable performance due to corrosion has highlighted the need for more accurate characterization of groundwater quality, particularly with respect to "unstable" variables which are primarily dependent on the partical pressure of oxygen and carbon dioxide. In addition, Australian ground waters are generally dominated by sodium and chloride, or sodium and bicarbonate, so that for the same conductivity and pH, they are more corrosive than the ground waters of Europe and North America for which rules-of-thumb for pump materials selection have been developed. Use of alternatives to cast iron and steel for various pump components could prove to be a major cost-saving tactic in the long run: austenitic stainless steel is highly promising despite considerable initial cost. Pump column corrosion appears to be as much a design problem as anything else. Some form of cathodic protection may ultimately be the best solution for such difficulty.
Specialized information centre services	J.W. Spaven, "The International Crops Research Institute for the Semi-arid Tropics", *Agricultural Administration* (Hyderabad, India), vol. 4, No. 1 (January 1977), pp. 49-55	The International Crops Research Institute for the Semi-arid Tropics (ICRISAT) was founded in 1972 as one of the nine international agricultural research groups operating under the Consultative Group of International Agricultural Research. The purpose of ICRISAT is to focus research on improving the principal food crops and farming systems of the semi-arid tropics, identify barriers to improvement, and supply findings to 48 participating local government agencies which develop recommendations for farmers. Initial efforts concentrated on India and the semi-arid nations of Africa. Crop improvement efforts focused on the following major food items crucial to local diets: sorghum, millet, pigeon pea, chick pea, and groundnut. Farming systems able to be broadly used, yet appropriate for making optimum use of a region's land and water are emphasized in ICRISAT's farming systems programme. The organization also emphasizes short-term, in-service training.
Waste treatment processes	R.L. Carpenter, M.S. Coleman and R. Jarman, "Aquaculture as an alternative waste-water treatment system", *Biological Control of Water Pollution*, (Philadelphia, University of Pennsylvania Press, 1976)	The use of aquaculture to upgrade waste treatment lagoons while producing a valuable by-product is being studied in a six-cell, serially operated experimental lagoon system. Fish were already present in the first two cells receiving conventional aerated treatment. The four non-aerated cells were variously stocked with channel catfish, golden shiners, fathead minnows, and Tilapia Nilotica. The secondary treatment standard for 5-day biological oxygen demand was met in the effluent from the second cell; standards for suspended solids and fecal coliforms were met in the effluent of the fifth cell. Removal of nitrogen and phosphorus was excellent. No pathogens were found in waste-water beyond the first two cells nor in any of the 179 fish sampled. Biomass

Subject	*Source*	*Description*
		increases were: 1.8 to 76 kgs for Tilapia nilotica; 270 to 1,800 kgs for channel catfish, 38 to 243 kgs for golden shiners. When operated in the absence of fish, effluent quality was lower and the suspended solids standard was not met.
Waste treatment processes	R. Dinges, "A proposed integrated biological waste-water treatment system", *Biological Control of Water Pollution*, (Philadelphia, University of Pennsylvania Press, 1976)	The proposed system intended to correct the deficiency of stabilization pond effluent quality consists of four serially-operated treatment ponds. Stabilization pond effluent in which original organic matter has been reduced by bacterial action and converted to algal cells will be passed through a pH reduction filter and into the proposed unit. The first pond will contain water hyacinths and duckweed; scuds will be abundant. Expected results are mineral nutrient uptake, reduction of hardness and total dissolved solids, denitrification, and suppression of algal growth. Results expected of the second pond, devoted to zooplankton culture, are clarification, organic and coliform reduction, and mineralization and mineral nutrient uptake. The third pond will contain larger invertebrates such as glass shrimp. Expected results are biomass conversion to a larger life form, nutrient uptake settling, and minimal organic reduction. Results of the fourth pond, which will contain fish, are biomass conversion to a larger life form, settling, and minimal organic reduction. By-product production may help offset the cost of treatment.
Waste treatment processes	R. Patrick, "The role of aquatic plants in aquatic ecosystems", *Biological Control of Water Pollution*, (Philadelphia, University of Pennsylvania Press, 1976), pp. 53-59	Aquatic plants enrich aquatic and wetland ecosystems by fixing carbon and giving off free oxygen during photosynthesis. They also provide shelter for aquatic organisms. In the growth of aquatic plants various nutrients are removed from the water. Nutrients may be accumulated in excess of what is needed for growth. Significant amounts of heavy metals are also accumulated. Nutrients and trace metals are stored in plant tissues and are returned to the aquatic ecosystem as food or detritus. In the case of emergent vegetation, they may be dispersed into the terrestrial ecosystem. Wetlands are important for the production of various substances essential for the aquatic ecosystem. An example is the production of vitamin B12 by fungi and bacteria in swamps.
Waste treatment processes	Joachim Tourbier and Robert W. Pierson, Jr., eds., *Biological Control of Water Pollution* (Philadelphia, University of Pennsylvania Press, 1976), p. 340	In the conference on biological control of water pollution, scientists, environmental experts and city planners from the Federal Republic of Germany, the Sudan, the Netherlands, Finland, Romania, the United States and Puerto Rico discuss how biological systems may be utilized to deal with water pollution problems. Papers are presented suggesting that green plants and biological systems have the capacity to detoxify dangerous synthetic chemicals in industrial wastes and that vegetation can capture nutrients and be harvested directly as food for man and domestic animals or used for paper manufacture or composting. More complex systems are also presented in which food chains are reconstructed from nature, beginning with green plants and phytoplankton and ending with animals of economic value. Biological

Subject	*Source*	*Description*
		systems are discussed which rely on forest, marsh or crop vegetation, together with soil micro-organisms, to improve the quality of aquifer recharge water.
Waste treatment processes	B.C. Wolverton, R.M. Barlow and R.C. McDonald, "Application of vascular aquatic plants for pollution removal, energy, and food production in a biological system", *Biological Control of Water Pollution* (Philadelphia, University of Pennsylvania Press, 1976), pp. 141-149	A 0.40 ha water hyacinth wetland has the potential for removing over 1,590 kg of nitrogen and over 360 kg of phosphorus annually from sewage effluent absorbing and metabolizing over 70 kg of phenol every 72 hours from phenol-polluted water and removing over 120 gm of trace heavy metals daily. Under favourable conditions, 0.40 ha of water hyacinth has the potential of producing over 65 tons of dry plant material annually. This can be converted, through anaerobic decomposition, to over 28,000 cu m of biogas; a high grade fertilizer is produced as a by-product. Water hyacinths may, eventually, be used as food for cattle and even man. Field demonstrations using a chemical waste lagoon and a municipal sewage lagoon are in process. Processing equipment, including scaled-up laboratory models of biogas generating units, is being developed.
Waste treatment processes	"Effective textile industry effluent treatment", *International Dyer and Textile Printer*, vol. 157, No. 4 (February 1977), p. 184	Dyeing processes in the textile industry often result in surges of highly toxic waste which can upset conventional waste-water treatment systems. The Whitehead and Poole oxidation ditch system is based on the completely mixed, rapid dispersion principle and is designed to accommodate a high sludge: organic load ratio. The rapid dispersion results in rapid transfer of oxygen throughout the tank. The manufacturers report that the Whitehead and Poole oxidation ditch system can produce an effluent which meets the British Royal Commission standards of 20 mg BOD/litre and 30 mg suspended solids/litre. A compact aeration system which operates on the same principles as the oxidation ditch but is contained within a vertical structure of steel or reinforced concrete is also available.
Waste treatment processes	H. Mannisto, E. Sebbas and E.N. Westerberg, "Energy vs Environment – Friends or foes", Canadian Pulp and Paper Association Technical Section, Environment Improvement Conference, Montreal, 6-8 October 1976, Preprinted Proceedings (Montreal, P.Q.), pp. 27-34	A case study of a single-line bleached kraft mill with a batch digester shows that a reduction in the pollutant load of effluents can be accomplished by in-plant controls and external treatment without increasing mill energy consumption. In-plant measures to minimize the water pollutant load include: closing the water system of the wet drum barkers; increasing the active alkali charge to the digester; closing the water system for pulp screening and adjusting water usage to an optimum dilution factor; closing the bleach plant water system; stripping the condensates from the digester and evaporator to allow reuse in brown stock washing and causticizing; and collecting and returning spills to process streams. The increase in the process heat consumption due to the in-plant measures is about 850,000 BTU/short ton of air-dry bleached pulp. The increase in power consumption is estimated to be 15 and 20 kWh/short ton for in-plant measures and external treatment, respectively. Because of more efficient recovery of the dissolved dry solids, the steam generation in the recovery boiler is increased by about 1,000,000 BTU/short ton. The power required for combined in-plant measures and

Subject	*Source*	*Description*
		external treatment can be generated as the by-product power. The heat consumption to generate 35 kw-hr/short ton is about 130,000 BTU/short ton, assuming heat consumption for back-pressure power generation is 3,600 BTU/kWh. After power generation, the increase in steam generation is thus 870,000 BTU/short ton, which corresponds almost exactly to the increase in process heat consumption.
Waste treatment processes	J. Orivuori, E. Sebbas and E.N. Westerberg, "Waste heat for evaporation of effluents", Canadian Pulp and Paper Association, Environment Improvement Conference, Montreal, 6-8 October 1976. Preprinted Proceedings (Montreal, P.Q.), pp. 55-60	A newsprint mill using 80 per cent groundwood and 20 per cent chemical pulp examined the feasibility of using waste heat generated in a closed water system for effluent evaporation. Heat balance calculations for the groundwood mill (power consumption 1,200 kWh/short ton of air-dry product with 15 per cent loss to the atmosphere and 30 per cent to vapour flash) show that there is a waste heat of 2,300,000 BTU/short ton which has to be removed by cooling of the groundwood mill's recycled water. The amount of water recirculating in the groundwood pulp mill is about 13,000 gal/short ton. This water volume must be cooled from 158 F (maximum allowable temperature of the groundwood pulp slurry) to 136 F (temperature of the paper machine white water) in order to keep the in- and out-going process heat flows in balance. Since there is no need for hot process water, and the temperature of the waste heat is relatively high, it is possible to utilize the heat for evaporation of the effluent. The reuse water from the ground-water mill is cooled in a heat exchanger and the waste heat is transferred to the effluent evaporator. An evaporation plant using waste heat would consume about 30-40 kWh/1,000 gal water. Preliminary cost estimates show costs of waste heat evaporation comparable with costs of external treatment methods.
Waste treatment processes	M.R. Overcash and F.J. Humenik, "State-of-the-art: swine waste production and pretreatment processes", National Technical Information Service, Springfield, VA 22161 (No. PB-267 995, December 1976)	A review of waste sources and pretreatment processes in the swine processing industry was presented as an over-all evaluation of various experimental and demonstration data. Various aspects of swine waste management and swine production are discussed, including housing types, the magnitude and distribution of swine, and population characteristics. Properties of swine waste and production unit waste load are presented for wastes from drylot and pasture production units and for concrete slab and slotted floor-pit wastes. Factors evaluated include type and size of animal, waste volume, solids content, nitrogen, cations, anions, bacteria and miscellaneous parameters. Various pretreatment processes are discussed with respect to altering the land-limiting constituents of swine waste, treatment for partial reuse, and complete recycling or reuse of swine wastes. Treatment processes for altering the land-limiting constituents include anaerobic lagoons, mechanically aerated lagoons, naturally facultative lagoons, rainfall runoff retention ponds, oxidation ditches, and overland flow. Treatment processes for partial reuse include high-rate anaerobic digestion with methane production, solids separation, pyrolysis, and refeeding processes.

Subject	*Source*	*Description*
Water in plants	C.F. Musil, C.H. Bornman, and J.O. Grunow, "Some observed interrelationships between the cover of aquatic vegetation and various physical properties of the water medium", *Journal of South African Botany*, vol. 42, No. 2 (1976), pp. 157-169	High pH and oxygen but low total carbon dioxide values were recorded from water at sites containing high percentage covers of predominantly submerged aquatic vegetation. The converse was true in water at sites containing very dense covers of predominantly rooted-floating and free-floating aquatic vegetation. The cover of submerged aquatic vegetation was influenced by the turbidity of the water and also by shading, particularly by that of floating aquatic vegetation.
Water in plants	W. Shepherd, "Indices of plant water status: some comparisons within and between crop species", *The Journal of Applied Ecology* (Australia), vol. 13, No. 1 (April 1976), pp. 205-209	The effects of plant water status on physiological processes have been widely studied using four indices of plant moisture: ratio of plant water content to dry weight, sap osmotic potential, leaf water potential, and leaf water vapour resistance. Relationships between the various indices are complex, but are important because of their relevance to crop growth modelling, studies of water movement in plants, and the resistance of plants to drought. Some relationships between the indices and transpiration have already been reported. This paper considers further data from potato, barley, and wheat crops, giving particular consideration to differences between crops grown under conditions of plentiful and limited water supply. The four indices were determined for the upper third of the canopy, and for the low part, the remainder of the leaves. The results are presented. The relationships were different for upper and lower levels of plants, and different crop species, grown under various water regimes. Crops raised with a limited water supply developed in ways that tend to restrict transpiration during subsequent periods of drought.
Water law and institutions	E.A. Ackerman and G.O. Lof, "Emerging technology and administrative organization for water development", in *Technology in American Water Development*, (Baltimore, Md., Johns Hopkins Press), pp. 628-657	Administrative means are needed for using new technology in a co-ordinated manner to aid in efficient water resources development and management. The authors strongly urge creation of regional administrative units which would be co-ordinated where necessary by an overriding national body. The most appropriate technical aids will differ from region to region. Among those discussed are: (1) weather modification; (2) desalting; (3) reuse of industrial and municipal water; (4) evaporation control; (5) water transfer; and (6) mining groundwater. Numerous administrative problems that have resulted from increased technology are explored, but the most pressing is the need for co-ordination and centralization of water management among federal, state, local and private sectors. Co-ordination is essential because of: (1) the increasing differentiation of water problems among the regions; (2) the need for different techniques among the regions; and (3) the eminent feasibility of administering water development on a regional basis. In addition, the federal establishment may be a better technical leader if it is less of an entrepreneur. By having both national and regional agencies, the most appropriate body is able to handle a particular management problem as it occurs.

Subject	*Source*	*Description*
Water law and institutions	E.M. Borgese, "International Ocean Institute", *Oceans*, vol. 10, No. 1 (January 1977), pp. 52-57	Increased accessibility to the ocean's vast resources made possible by the technological revolution makes an international race for exploitation with consequent conflict and pollution inevitable. Since the old law of the sea based on the sovereighty of coastal states within a three-mile territorial limit is inadequate, a new concept, the common heritage of mankind, should take its place. The United Nations helped to found the international Ocean Institute at the University of Malta. The purpose of the Institute is to study the establishment of a new international order in the oceans and to propose new approaches and solutions. The Institute held a seminar on pollution of the Mediterranean and examined the existing pollution control legislation in all the Mediterranean States. The Institute's three-step plan for the Mediterranean area includes: (1) strengthening of existing regional bodies and institutions; (2) creating new bodies for regulating unregulated uses of marine areas; and (3) co-ordination of the policies of the various agencies and Governments involved. The Institute's work is not limited to the Mediterranean: studies of a new international economic order and of the law of the sea convention are also under way.
Water law and institutions	T.A. Clingan, Jr., "Four monographs for the general reader (World Oceans, Law of the Oceans, Institutional Arrangements for the Law of the Sea, Work of the Third United Nations Conference on the Law of the Sea)", Sea Grant Special Report No. 10, February 1977	Man has just begun to utilize the natural resources of the sea. These four monographs examine the physical and political difficulties involved in the use of oceanic resources and the international law that must deal with these problems. The old international law based on custom, combined with the unilateral actions and bilateral agreements of some nations, was often unable to deal with modern problems. In an effort to resolve these conflicts, the United Nations held a series of three conferences on the law of the sea. The first, held in 1958, resulted in four conventions dealing with high seas, territorial sea, continental shelf, and fishing and conservation. None has been widely ratified. The second, in 1960, resolved nothing. The third conference, to be held soon, must deal with the peaceful exploitation of living and non-living resources, and the preservation of the marine environment. The principle of the "common heritage of mankind" must compete with the rights of States and individuals to have access to oceanic resources. The author believes that a treaty will emerge from the conference only if each country is willing to make some extremely painful decisions.
Water law and institutions	S.W. Hays, "The effects of the 200-mile United States fishing zone", *Louisiana Law Review*, vol. 37, No. 4 (Spring 1977), pp. 852-874	Increased consumer demand and new technological developments, such as processing and freezing at sea, improved synthetic webbing in net fishing, and new frozen fish products have created the need for fisheries conservation. Four United Nations conferences on the Law of the Sea have failed to decide the breadth of the territorial sea and the interests of coastal States in the fishery resources of their coasts. To hasten negotiations, the Conference adopted a negotiating text which advocated a 200-mile exclusive economic zone. Recognizing that any fishery management treaty would provide some type of economic zone, Congress passed the Fishery

Subject	Source	Description
		Conservation and Management Act which established a 200-mile fishery conservation zone around the United States. Foreign nations began enacting their own 200-mile zones, implicitly ratifying the United States' action. The author assesses the impact of the Act on the anadromous sedentary and highly migratory fish species, and on the coastal fishing industry and the Gulf Coast fishing industry. The Act finally provides the United States with a statutory basis from which to develop and enforce a unified fishery management plan.
Water law and institutions	B.H. Oxman, "The Third United Nations Conference on the Law of the Sea: the 1976 New York sessions", *The American Journal of International Law*, vol. 71 (April 1977), pp. 247-269	The purpose of the United Nations Conference on the Law of the Sea was to formulate an international treaty. There are two major problem areas which must be resolved before any treaty can be finalized. The first problem is the dispute between the industrialized and developing nations over exploitation of deep sea-bed mineral resources. The author indicates this is largely symbolic since each nation has individual interests. Ultimately, what must be settled is how the sea-beds will be partitioned while preserving a universal right to their use. The second problem is the proposed creation of 200-mile economic zones surrounding coastal States. Concern here centres on whether these States will attempt to assert power beyond the areas allowed, i.e. fishing rights, vessel pollution, some scientific research. For most purposes, the economic zone would retain the same status as high seas. The author concludes that a settling of these problems and final passage of the treaty will contribute not only to agreement concerning the sea, but also to increasing world-wide stability and consequently to a decrease in international tensions.
Water law and institutions	"Report of the United Nations Water Conference, Mar del Plata, 14-25 March 1977", New York, United Nations Water Conference	The Mar Del Plata Action Plan made recommendations in the following areas: assessment of water resources; water use and efficiency; environment, health and pollution control; policy, planning and management; natural hazards; public information, education, training and research; regional co-operation; international co-operation; specific regional recommendations. It also adopted resolutions on the following topics: assessment of water resources; community water supply; agricultural water use; research and development of industrial technologies; role of water in combating desertification; technical co-operation among developing countries in the water sector; river commissions; institutional arrangements for international co-operation in the water sector; financing arrangements for international co-operation in the water sector; water policies in the occupied territories.
Water law and institutions	M. Ruivo, "Oceanography and Law of the Sea", *UNESCO Courier*, vol. 30 (January 1977), pp. 10-13	As marine science is increasingly applied for peaceful as well as military and security purposes, contradictions arise between maritime practice and traditional maritime law. To resolve such conflicts, two Conferences on the Law of the Sea developed provisions for regulation of scientific research. The guidelines maintained the prin-

Subject	*Source*	*Description*
		ciple of freedom of the seas except for the Continental Shelf area and provided that coastal States should not normally withhold consent to a legitimate research request as long as that State could participate. However, newly independent nations question the equity of the proposals. Recently, through agencies such as UNESCO's Intergovernmental Oceanographic Commission, cooperation in oceanographic research, although still dominated by industrialized countries, has increased in all continents. Developing countries remain uneasy about research regulations because they are convinced of their need to control and benefit from the information derived from research activities to protect their interests, including national defense. Success of the new rules for oceanographic research depends upon negotiation and compromise in a spirit of international cooperation.
Water law and institutions	R. Winner, "Marine Scientific research and the Law of the Sea Conference: Some proposed amendments to the revised text", Technical Report WHOI 76-80, Woods Hole Oceanographic Institution, MA (WHOI), September 1976	International treaty provisions and negotiations affecting marine scientific research are under consideration at the fifth session of the United Nations Conference on the Law of the Sea. The author addresses those aspects of the negotiations that directly affect marine scientific research. He bases his analysis principally upon a study of the first single negotiating text produced at the third session, contrasting this with the revised single negotiating text produced by the Conference at the fourth session. Topics discussed include: (1) the nature of the divergent interests the treaty negotiations are trying to conciliate; (2) the treaty provisions and international law dealing with marine research before the Third Conference; (3) the direction indicated by the third session negotiations; and (4) recommended amendments to the revised text. Particularly examined are the texts of the three committees on the conference. Committee I deals with the law of the deep sea bed beyond the claims of national sovereignty; Committee II has responsibility for defining the geographic limits of, and substantive rights within, the territorial sea, economic zone, and high sea. Committee III is concerned with marine environmental protection and preservation, marine scientific research, and technology transfer.
Water quality control	*Proceedings of the International symposium on marine pollution research*, National Technical Information Service, Springfield, VA 22161 (No. PB-267 601, January 1976)	Symposium papers discuss how man's activities have affected natural resources of a coastal environment. Participants, discussing international aspects of coastal pollution, reviewed the current status of research and procedures planned to minimize offshore coastal damage. Subjects included: "An Overview of the United States Environmental Protection Agency (USEPA) Programme in Marine Pollution Research", Carl R. Gerber; "Responsibilities for Marine Pollution Research Within Federal Agencies of the United States", Norman L. Richards; "Overview of Marine Pollution Research in the Baltic", K. Rozdzynski; "Marine Pollution Research in Yugoslavia: An Overview", V. Pravdic; "Over-

Subject	Source	Description
		view of Marine Pollution Research in Egypt", Saad El-Wakeel; "Overview on Pollution in the Coastal Environment of Pakistan and its Possible Implication for the Marine Ecosystem", S.M. Haq; "Overviews on Marine Pollution in India", K. Rangar Rao; "Research Needs Concerning Pollution of the Marine Benthos", R.C. Swartz; "Hydrological, Chemical and Physical Processes Affecting Pollution of the Baltic Sea", A. Trzosinska; "Investigation of Pollution-stressed Littoral Communities in the Northern Adriatic", D. Zavodnik; "Microbiology and Chemistry of Estuarine Surface Microlayers", A.W. Bourquin and D.G. Ahearn; "Survival of Viruses in the Marine Environment", George E. Schaiberger, Charles P. Gerba and Enrique G. Estevez; "Relationship of Marine Pollution to Human Health", Ronald Engle; "Bioassays as Indicators of Pollution Effects", David L. Coppage.
Water quality control	S.K. El-Wakeel, "Overview of marine pollution research in Egypt", *Proceedings of the International Symposium on Marine Pollution Research*, held at Gulf Breeze, Florida, 27-29 January 1976 (EPA Report No. EPA-600/9-76-032, January 1976)	Several Egyptian institutions are involved in aquatic pollution problems, especially the Water Pollution Laboratory at the National Research Centre, Cairo. Their main areas of interest are water quality and industrial waste in the Nile and its tributaries. The untreated sewage of central Alexandria (over 2 million inhabitants) is discharged into the sea through a pipe constructed in 1954. There are, additionally, several emergency openings along the coastline. Thus, it is possible that the Alexandria beaches will be the first national recreation area to be polluted, with the anticipated effect on area sea food. One third of Egypt's industrial activity is located in the government of Alexandria where several factory complexes exist, mainly an oil refinery, paper mills, textile and cement manufacture, chemical industries and copper works. An oil pipeline terminal, connecting the Gulf of Suez with the Mediterranean, will reach the sea about 50 km west of Alexandria and will transport about 80 million tons annually, with a possible increase to 120 million tons. Although all precautions have been taken, there is still the possibility of oil spills at this site during loading operations. In view of this situation, two inter-institutional projects on aquatic pollution have been recommended to the Council of Environmental Research. They are: effect of sewage disposal in the sea on the water quality along the beaches of Alexandria and pollution control in Lake Maryout.
Water quality control	S.M. Haq, "Overview on pollution in the coastal environment of Pakistan and its possible implication for the marine ecosystem", *Proceedings of the International Symposium on Marine Pollution Research*, held at Gulf Breeze, Florida, 27-29 January 1976 (Report No. EPA-600/9-76-032, January 1976)	Pakistan has a 880-km long coastline with more than 51,800 sq km of area as part of the continental shelf. There is evidence that both natural factors and man's activities in the Karachi region are effecting drastic changes in its environment. To deal with problems of resource conservation and protection of coastal environments, it is imperative that factors complementing the change be thoroughly examined. The Government of Pakistan, recognizing the importance of all types of pollution on human health and on future resources, has recently established a Man and Biosphere Committee

Subject	*Source*	*Description*
		at the national level. The object of this committee is to initiate steps to study various aspects of environmental hazards caused by human activities and to develop measures for controlling future environmental pollution.
Water quality control	K.R. Rao, "Overviews on Marine Pollution in India", *Proceedings of the International Symposium on Marine Pollution Research*, held at Gulf Breeze, Florida, 27-29 January 1976 (EPA Report No. EPA-600/9-76-032, January 1976)	India is the second most populous and the seventh largest country in the world. It has a coastline of 6,083 km. Marine pollution is associated with the drainage of domestic and industrial wastes directly into coastal waters or indirectly via river waters. Since independence, India has launched and is making significant progress in programmes for socio-economic development. Associated with the progress in industrial development and exploration of new energy reserves and pest control, there is evidence of environmental pollution. The belief that environmental disruption affects less developed countries in a lesser way is not well founded. Highly industrial pockets and overpopulated towns exist in the coastal areas, where marine pollution phenomena often appear with unparalleled intensity unless adequate preventive measures are adopted. Pollution is certainly a symptom of modernity which comes well in advance of other more desirable features of industrialization. Therefore, developing countries such as India have more opportunity to operate on a preventive basis than developed countries.
Water resources planning	J.F. Dwyer, J.R. Kelly and M.D. Bowes, "Improved procedures for valuation of the contribution of recreation to national economic development", National Technical Information Service, Springfield, VA 22161 (No. PB-274 446, September 1977)	Improved procedures are presented for evaluating the contribution of recreation to national economic development. These procedures are to replace those outlined in the Principles and Standards for Planning Water and Related Land Resources. Desirable criteria for valuation procedures are specified. Variation procedures currently used by federal agencies make almost exclusive use of the "interim unit day value approach", sometimes augmented by point systems. This approach has little theoretical or empirical justification and modification of the "interim unit day value approach" and the use of point systems is not a useful method of developing improved procedures. Rather, it is recommended that models be developed to predict individual willingness-to-pay for many types of recreation as functions of site characteristics, the characteristics of the individual user (including the history of previous use), the availability of substitute activities and sites, and the location of the individual in relation to the resources under study. The total value of the resource would then be a function of these variables, the number of users, and the distribution of users within the market areas. These functions may be derived from regional travel cost demand functions (which would also provide estimates of use) or could be explicit willingness-to-pay functions derived from the survey method (which must be supplemented by a use estimate). Examples of the desired models are provided along with guidelines for their development and use. Needs for further research are identified.

Subject	*Source*	*Description*
Water yield improvement	T.E. Gass, "Well redevelopment: Part II", *Water Well Journal*, vol. 31, No. 10 (October 1977), pp. 20-21	Clogging of a well screen and the adjacent formation due to iron bacteria is caused by slimy organic material produced by the bacteria and the iron deposits associated with the organism. These materials may combine with scale minerals such as calcium carbonate. Treatment must, therefore, include a bactericide as well as a strong acid to dissolve scale. Hydroxyacetic acid can be used as such a dual-purpose agent, but many drillers prefer a three-step treatment method involving shock chlorination, acidization, and a final shock chlorination. Potassium permanganate is a strong oxidizing agent that can also be used to treat incrustation. For removing silt and clay from a well, sequestering agents such as sodium phosphate can be used to disperse small practicles, making them easier to pump out. Surfactants, or wetting agents, can be used to enhance the dispersing efficiency of sequestering agents for the removal of silt and clay. Explosives and sonic well cleaning are two mechanical methods that can be employed in cases where chemical means are inapplicable. No matter what causes declines in well yield, it is always easier to redevelop the well if the problem is diagnosed early and treatment is applied before the well deteriorates to below 50 per cent of original specific capacity.

كيفية الحصول على منشورات الامم المتحدة

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